MAR 1 1924

MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

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HERBERT HOOVER
Secretary of Commerce

MARCH 1924

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 46 March, 1924 Number 3

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Price 60 Cents a Copy, $5.00 a year: to Members and Affiliates, 50 cents a Copy, $4.00 a year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

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A. R. MUMFORD

D. P. COOK

Underwood & Underwood
D. R. BLACK

PAUL HEYMANS

Contributors to this Issue

A large telescope should appeal to the imagination of the mechanical engineer as no other device can. In its design and construction it demands the skill of the scientist, the experience of the engineer, and the touch of the artist. Completed, it reveals to mere man a few of the wonders of a magnificent universe.

But the Perkins Observatory telescope described in this issue has a greater appeal than an ordinary large telescope, for its conception is that of a man who gave the effort of his lifetime that posterity might revel in the heavenly beauties and reap the benefit of studies made possible by his toil and sacrifice.

* * * * *

E. H. Brown and **M. K. Drewry,** who write on Economic Characteristics of Stage Feedwater Heating by Extraction, are both associated with the Allis-Chalmers Manufacturing Co., of Milwaukee, Wis. Mr. Brown has been actively engaged since 1909 in experimental and development work relative to power-plant equipment, and since 1916 has had charge of all acceptance tests of steam turbines manufactured by the company. Active field engineering in general power-plant equipment has given him a broad range of experience in past and present power-plant practice.

Mr. Drewry is engaged in steam-turbine work for the company. He was graduated in 1922 from the mechanical-engineering course of the University of Wisconsin.

* * * * *

Douglas P. Cook, president of the Boston Pressed Metal Co., Worcester, Mass., is particularly qualified to write on Pressed-Metal Engineering because of his long association with the work. Mr. Cook was born in Worcester in 1884. He was graduated with the class of 1905 from Harvard University. In 1907 he entered the employ of the Boston Pressed Metal Co., of which he became president in 1921. From 1918 to 1920 Mr. Cook was president of the Pressed Metal Association.

* * * * *

Paul Heymans and **Arthur L. Kimball** present in this issue a paper on Stress Distribution in Rotating Gear Pinions as Determined by the Photoelastic Method. Dr. Heymans was born in Ghent, Belgium, in 1895. From 1913 to 1920 he attended the University of Ghent and L'Ecole Spéciale des Travaux Publics in Paris, receiving the degree of Doctor in Engineering Science. The year 1920–21 he spent, as a fellow of the C. R. B. Educational Foundation, at the Massachusetts Institute of Technology, where he received the degree of D.Sc. He is now assistant professor in the physics department of M.I.T., in charge of courses in theoretical and advanced physics, elasticity, and photo-elasticity.

Mr. Kimball was graduated from Amherst College in 1908. In 1914 he received the degree of M.M.E. from Harvard Engineering School and the following year became assistant electrical engineer for the Interborough Rapid Transit Co. During the year 1917–1918 Mr. Kimball taught mathematics at Amherst. Since that time he has been research physicist at the research laboratory of the General Electric Co., Schenectady, N. Y.

* * * * *

Archibald Black and **Donald R. Black** are co-authors of the paper on the Commercial Possibilities of the Airplane. Born in Scotland, they came to this country in 1905. Mr. Archibald Black was educated in Cooper Institute, Cass Technical Institute, and Columbia University. In 1915 he entered the employ of the Curtiss Aeroplane Co. Thereafter he was associated successively with the L. W. F. Engineering Co., the Bureau of Construction and Repair of the U. S. Navy, and the firm of A. & D. R. Black, consulting engineers. He is now a consulting engineer in Garden City, N. Y.

Mr. Donald R. Black attended Cooper Institute, Pratt Institute, and the Polytechnic Institute of Brooklyn. He was engaged for several years in the design of heavy machinery and in 1916 entered the employ of the Curtiss Aeroplane & Motor Corporation. He was later associated successively with Maximilian Schmidt, the Aeromarine Plane & Motor Corporation, the L. W. F. Engineering Co., and A. & D. R. Black, consulting engineers.

* * * * *

A. R. Mumford, fuel engineer with the New York Steam Corporation, is the author of Furnaces for Burning Small Sizes of Anthracite. Mr. Mumford was born in 1895 in Boston, Mass. He was graduated in 1918 from the Massachusetts Institute of Technology with the degree of B.S. in electrochemical engineering, and then entered the service of the U. S. Navy. In 1919 he joined the Fuels Division of the U. S. Bureau of Mines as assistant fuels engineer, resigning in 1923 to accept his present position.

* * * * *

Arthur M. Greene, Jr., who contributes the article on The Binary Cycles Using Mercury and Steam, is dean of the school of engineering at Princeton University. Doctor Greene is a graduate of the University of Pennsylvania. He was previously associated with Rensselaer Polytechnic Institute as professor of mechanical engineering.

* * * * *

John H. Lawrence, engineering manager of Thomas E. Murray, Inc., New York City, is the author of A Résumé of Recent Power-Station Developments. Mr. Lawrence was graduated from Cornell University in 1909. He was formerly assistant mechanical engineer with the New York Edison Co.

* * * * *

Robert L. Sackett, whose paper on Industrial Education in Great Britain was delivered at the Conference on Education and Training at the 1923 A.S.M.E. Annual Meeting, is dean of engineering at Pennsylvania State College where he is in charge of the civil, electrical, and mechanical engineering departments.

A.S.M.E. Spring Meeting

Cleveland, Ohio, May 26-29, 1924

Preliminary plans indicate that this will be the most popular Spring Meeting. Watch the current issues of the A.S.M.E. News for details.

MECHANICAL ENGINEERING

Volume 46 March, 1924 No. 3

A New 60-In. Telescope for Perkins Observatory, Ohio Wesleyan University

A NOTEWORTHY addition to the ever-increasing number of large telescopes used for astronomical research is a 60-in. reflecting telescope recently completed by The Warner & Swasey Company, of Cleveland, whose past achievements in this line are widely known. Edward P. Burrell, Director of Engineering, is responsible for the design of this instrument, as he has been for all of the large telescopes built in recent years by the company.

This new instrument has been built for the Ohio Wesleyan University and is the realization of the ideal of a loyal and enthusiastic member of its faculty who retired some time ago after serving his institution for fifty consecutive years. Early in his youth Professor Perkins conceived the idea of acquiring a large telescope to enable students of the university to become familiar with the science of astronomy to furnish a means of inspiration and profound respect for the power of the Almighty. With this in mind he set himself the task of providing the funds which would ultimately be used for the realization of his ideal. By the practice of the most rigid economies on every hand and by the most scrupulous care in investing the savings from his income as an instructor, and later as professor in the university, he succeeded in accumulating a sum which some time ago was turned over to the university with the request that it be used for the purpose already described. Accordingly the project was undertaken without delay and, to the great satisfaction of all interested, the fund was found sufficient not only for the purchase of the instrument, but for acquiring the site and erecting the necessary observatory in which to house the great telescope.

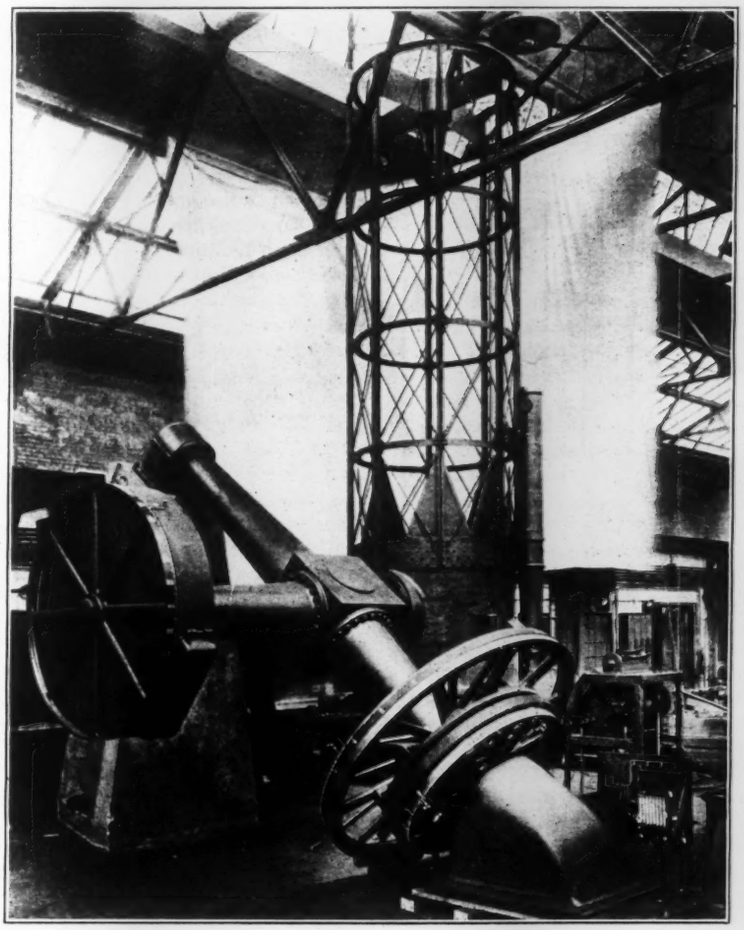

FIG. 1 60-IN. REFLECTING TELESCOPE DESIGNED AND CONSTRUCTED FOR THE PERKINS OBSERVATORY, OHIO WESLEYAN UNIVERSITY

(General view taken from west side of instrument, showing Cassegrain combination in position and mirror protection shutter wide open.)

It was at first planned to erect the new observatory on the site occupied by the old one on the campus; but upon studying the conditions of atmosphere and the interference from smoke and reflected light of the neighborhood, it was considered desirable to locate the new observatory on more favorable ground beyond the limits of the city of Delaware. Accordingly a very desirable location has been selected and the work of construction of the new observatory is now under way.

TYPES OF TELESCOPES NOW USED

Of the two types of present-day telescopes the reflector is increasing in popularity and use for astronomical purposes, despite the remarkable record made in past years by its contemporary, the refractor. Both types of telescope have been known to science since the very early days of astronomy and the two have been used extensively both in Europe and in America, but the adaptation of photography to astronomical research has emphasized the advantages of the reflecting telescope. In visual observation, increased time of observation does not greatly increase the amount of detail seen, for instance, in the structure of a nebula. Photography, on the other hand, yields an increasing amount of detail with increased time of exposure of the plate, thus bringing within the range of human vision objects that would otherwise be beyond the reach of the keenest eyesight. Moreover a permanent and accurate record is thus obtained and the comparison of plates has led to the discovery of "novæ" or new stars. A single night's work with the camera or spectrograph may thus produce material for many hours of measurement and calculation. The reflecting telescope is especially well adapted for use in photographic work as it is free from the disadvantage of color aberration and its optical parts are obtainable in sizes that permit a maximum of light-gathering power, the latter feature decreasing the time required for photographic exposures.

Since the reflecting telescope is seldom used for other than astronomical work, a brief comparison of that type of instrument with the more familiar refracting type, of which the ordinary spy glass is an example, may be of interest. The optical principle used in both types of telescope may be stated as follows: An object glass, or objective, brings to a focus parallel rays of light and the image thereby produced on the focal plane is enlarged by a suitably located magnifying glass or eyepiece, the degree of enlargement being in the ratio of the focal length of the objective to that of the eyepiece.

In the refracting telescope the objective is a lens, through which the light passes, the quality of the image thus depending not only

upon the curvature of the surfaces of the lens, but also upon the refractive and dispersive qualities of the glass itself, together with its freedom from internal strains and imperfections. The difficulty of obtaining a very large piece of glass of suitable quality for a lens is easily understood, but the fact that the lens must be comparatively thin to avoid loss of light and hence has a tendency to sag when in use and thus distort the image, is not so generally appreciated. This sagging is of course extremely slight but is optically objectionable; sufficiently so, in fact, to render the use of a lens larger than 40 in. in diameter a matter of doubtful feasibility for an equatorial

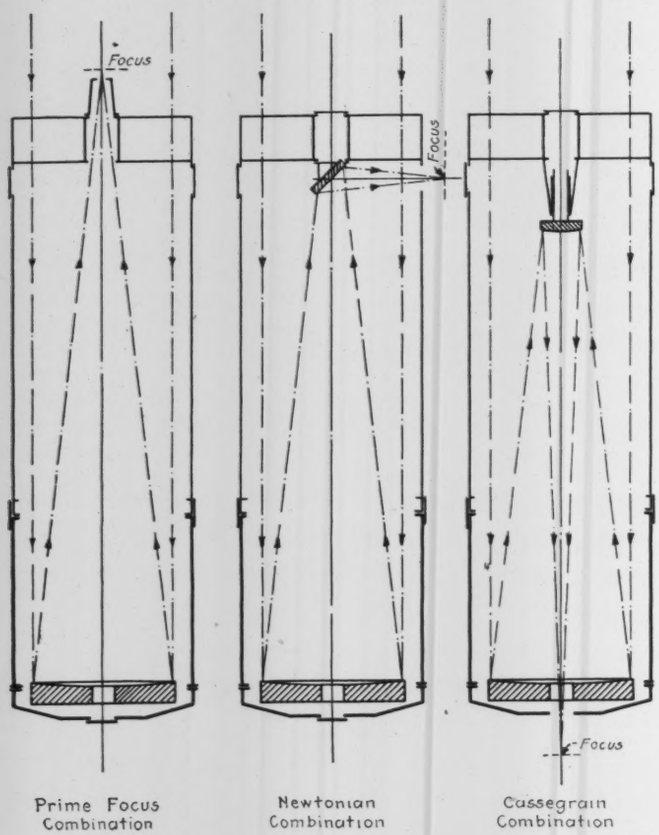

FIG. 2 OPTICAL COMBINATIONS COMMONLY USED IN REFLECTING TELESCOPES

telescope. The refractor, however, has certain advantages and is well suited to visual work in connection with double stars and the surface details of planets.

In the reflecting telescope the objective is a mirror which reflects the incoming rays of light from its silvered concave surface of parabolic contour, thus bringing the rays to a focus without the color distortion or aberration that is inherent in the refracting type. There is, of course, a certain loss of light in reflection and the silvered surface must be renewed at intervals to keep the loss at a minimum. The quality of the glass used for a mirror is of somewhat less importance than that used for a lens, although there must be no surface imperfections nor internal strains in the mirror. It is practicable therefore, to make reflecting telescopes of very great light-gathering power, and while a mirror 72 in. in diameter and one even larger have been made, it is probable that the ultimate limit of size has not yet been approached. The quantity of glass required for one of these large mirrors is such that the manufacture of a suitable glass disk is a matter of considerable difficulty. In the new instrument the mirror is slightly in excess of 60 in. in diameter, 9 in. thick at the edge, and has in its center a hole $8\frac{1}{2}$ in. in diameter. Its weight is close to 2700 lb. Although massive in its proportions, and of a rigid material, such a mirror is very sensitive to inequalities in support, tending to sag between supports, which would result in a distorted image, but at the same time it must be mounted movably so as to align its optical axis with the axis of the telescope tube. These conflicting conditions require great care in designing the mirror supports. The mirror is also very sensitive to changes in temperature, expansion of the glass altering the contour or "figure" of the polished surface. For this reason care must be taken to protect the mirror from variations in temperature, keeping it as nearly as possible at the temperature of the air to which it will be exposed when in use. Protective measures used on this instrument are described later in this article.

OPTICAL COMBINATIONS USED IN REFLECTING TELESCOPES

Diagrams of the three optical combinations that are most commonly used in a reflecting telescope are shown in Fig. 2. The prime-focus combination is best suited to photography as it involves a single reflection and hence the least possible loss of light. In the Newtonian combination the disadvantage of a second reflection from the diagonal plane mirror is balanced against the more accessible location of the observing position. In both of these combinations the magnification obtainable is in the ratio of the focal length of the primary mirror to that of the eyepiece. For some purposes, particularly in work with the spectrograph, it is desirable to use a greater focal length than that of the primary mirror, in which case the Cassegrain combination is used. In this combination the secondary mirror is of a hyperbolic contour and, receiving the beam of light from the primary, reflects it back along the same axis through a hole in the primary to a focus some distance below the mirror cell. The equivalent focal length of the combination is much greater than that of the primary alone, permitting a high degree of magnification, theoretically, although atmospheric conditions rarely permit the possibilities in that direction to be fully utilized. The spectrograph with its own optical system is attached to the lower surface of the mirror cell as described further on. The function of the modern astronomical telescope is, of course, to permit the continuous observation of a star or other celestial object as it appears to move across the sky. To accomplish this purpose to the best advantage, the entire optical system is usually mounted so as to rotate about an axis parallel to the earth's axis (i.e., perpendicular to the celestial equator, hence the term "equatorial mounting"), while motion about an axis perpendicular to the above is also provided in order that the telescope may follow an object on any circle parallel to the celestial equator.

The use of these instruments for photography, which often requires the exposure of a plate for a number of hours, makes it particularly necessary that the motion from east to west should be free from periodic variations and accurately timed to the normal sidereal rate, although means must also be provided for comparatively rapid motion of the instrument when changing the field of view or "setting," as well as for making minute corrections of rate to compensate for the effects of atmospheric refraction. When it is considered that the moving parts of this instrument weigh 30 tons, that uniformity of motion requires them to be carefully balanced about both axes, and that the optical parts must be held accurately in their proper relation, a condition requiring rigidity of construction, it will be seen that the design of a large telescope, while affording considerable latitude of choice, requires great care in order to combine the best proportions of all parts with a minimum of total weight.

THE TUBE OF THE OHIO WESLEYAN TELESCOPE

The description of this telescope should naturally begin with the tube, for this is the element which holds in alignment the optical parts of the instrument. The tube is made up of three main sections: the center piece or central section, a heavily ribbed cylindrical casting 6700 lb. in weight, having on its side the seat for the declination axis; the lower section, or mirror cell, which houses the great mirror and its supporting mechanism; and the tube proper, a skeleton section, made of structural steel T-bars, firmly riveted together and stiffened with tie rods and turnbuckles, as shown in the Figs. 1, 3, and 4. These tie rods perform the important function of reducing to a minimum the element of deflection. They provide great rigidity in every position of the tube, and tests have shown that the maximum deflection even in the horizontal position is well within the narrow limits set by the optical requirements. At the upper end of the tube will be noted four radial vanes which carry a support for the secondary mirror. Two secondaries are furnished, the Newtonian, Fig. 5, being a diagonal flat $17\frac{1}{2}$ in. in diameter, so, arranged that it may be made to face either of the two adapters

shown on opposite sides of the tube near the upper end. The Cassegrain, Fig. 6, is a convex mirror, 16 in. in diameter, mounted facing the primary mirror and adjustable in position along the axis of the tube so as to permit focusing, which is done by means of a handwheel mounted just below the mirror cell and a shaft running up the outside of the tube. The secondaries are readily removable and when neither is in place the prime-focus position may be used by removing the focusing screw and attaching an adapter to the outer surface of the secondary support.

At the lower end of the skeleton tube is a flanged ring which carries a protective shutter consisting of eight triangular leaves (Figs. 1 and 3). These overlap when shut down over the mirror (Fig. 4), and form a complete protection against mechanical injury as well as against changes in temperature. The shutter is operated by a handwheel on the under side of the mirror cell and a shaft connecting with a worm gear at the base of the tube.

The function of the center piece, to which the tube is securely bolted, is principally to support the tube and the mirror cell. Being itself supported only on the side where the flange of the declination axis is bolted to a tapered seat, it is heavily ribbed and flanged to secure the utmost rigidity.

FIG. 4 GENERAL VIEW OF OHIO WESLEYAN TELESCOPE TAKEN FROM WEST SIDE OF INSTRUMENT
(Shows Cassegrain combination in position and mirror protection shutter partly open.)

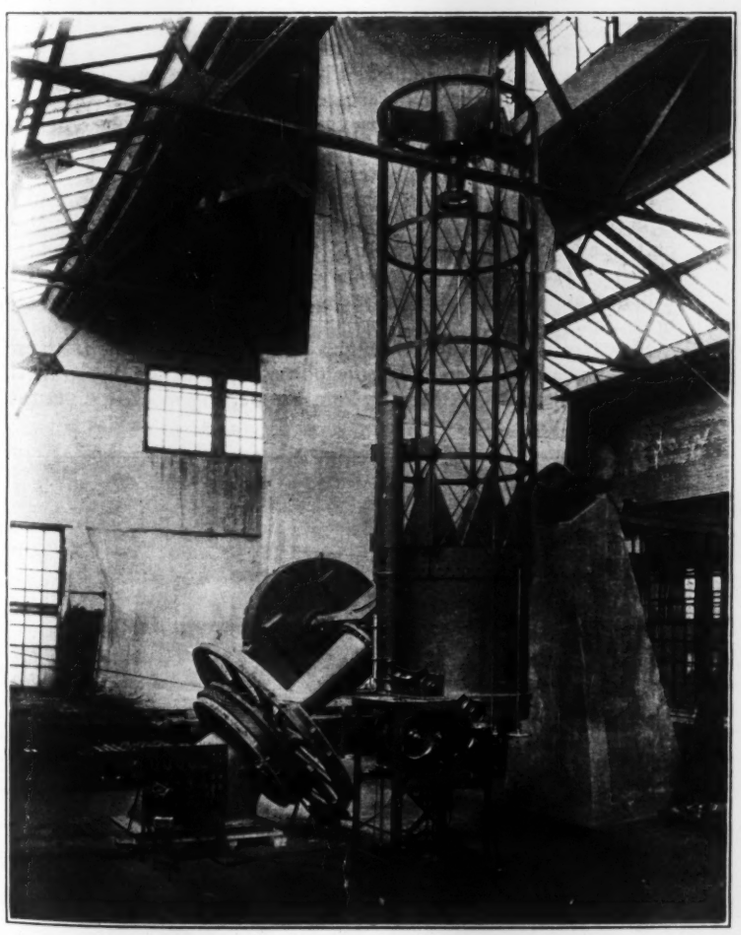

FIG. 3 GENERAL VIEW OF OHIO WESLEYAN TELESCOPE TAKEN FROM EAST SIDE OF INSTRUMENT
(Shows Cassegrain combination in position and mirror protection shutter wide open, with driving clock in the foreground.)

The mirror cell, which is bolted to the lower flange of the center piece, contains the supporting system for the primary mirror. This consists of three multiple pans equally spaced and supported by screws for collimation, while four side blocks bearing against screws afford further adjustment of the optical axis. Cork pads insure even distribution of pressure over the contact areas, and the system as a whole provides rigid and well-distributed support for the mirror in whatever direction the telescope may be pointed.

The entire outer surfaces of the mirror cell and tube center piece are to be covered with a thick layer of insulation in order that the mirror may be kept from variations in temperature to which, as already noted, these mirrors are very sensitive.

On the under side of the mirror cell provision has been made for mounting a spectrograph. This consists of a movable ring mounted on a tapered support and held by carefully fitted brackets, one of which houses a worm that rotates the ring. The spectrograph will be bolted to the ring and accurately centered by a tapered flange. Rotation is obtained by a handwheel and shaft connecting to the worm. In place of the spectrograph there is at present mounted an adapter containing sufficient weight to make it interchangeable with the spectrograph without altering the balanced condition of the instrument. A few counterweights have been added to afford accurate adjustment of balance, but in this connection it may be noted that the instrument has been so proportioned that the use of removable weights has been rendered unnecessary to an extent that is quite unusual in large telescopes.

THE POLAR AXIS

Rotation in the east-and-west direction is provided by the polar axis, the name of which is derived from the fact that it points to the pole of the heavens and is so mounted as to be exactly parallel to the earth's axis. It is made up of three heavy steel castings, securely bolted together. The center section is a hollow cube measuring 3 ft. on each edge, through which the declination axis, to be described later, passes. The

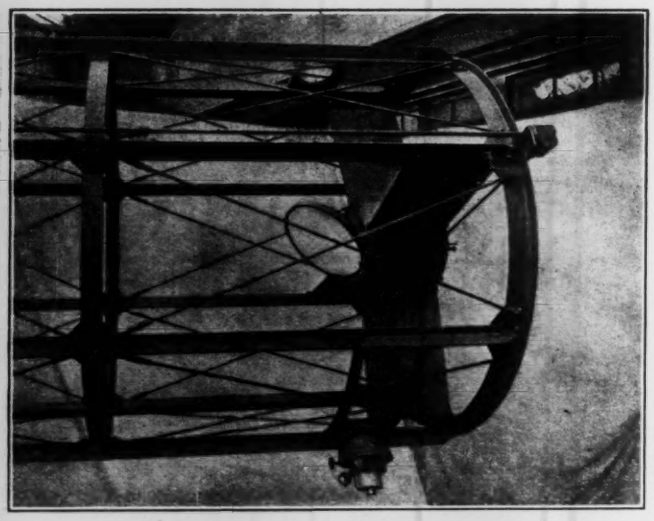

FIG. 5 VIEW OF UPPER END OF TUBE WITH NEWTONIAN ARRANGEMENT IN POSITION

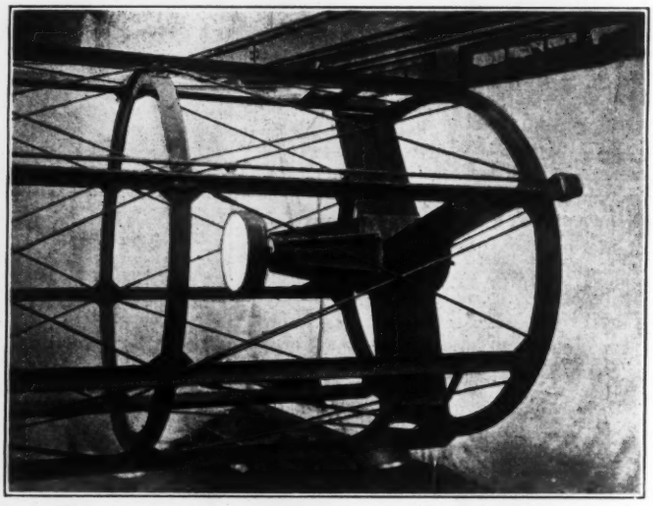

FIG. 6 VIEW OF UPPER END OF TUBE WITH CASSEGRAIN ARRANGEMENT IN POSITION

upper and lower sections of the polar axis are slightly conical in shape, and have at their smaller ends forged-steel extensions upon which are mounted self-aligning radial ball bearings. These bearings are carried in heavy cast-iron boxes called the "pier heads," which are designed to support the great weight of the instrument as well as protect the bearings. In the upper or north pier head are screws for adjusting the position of the polar axis both vertically and horizontally to insure exact parallelism with the earth's axis. In the lower or south pier head are both self-aligning ball-thrust and radial-thrust bearings. These receive the axial thrust, amounting to slightly more than half the total weight of the moving parts of the instrument.

The lower extension of the polar axis also carries the gears and graduated circles necessary for providing and indicating the east-to-west or "right ascension" motion of the telescope. The smaller circle, known as the hour circle, is keyed to the polar axis and, in connection with the indexes carried by brackets on the south pier head, indicates the "hour angle" of any celestial object toward which the telescope may be pointed. The larger circle, called the sidereal circle, is so mounted on the hub of the driving wormwheel that it may be independently rotated about the polar axis. The observer, having started the driving clock and set the instrument by means of the hour circle to a known position in right ascension, may then, by referring to his sidereal clock, set the larger circle to read sidereal time. This circle then is allowed to rotate with the driving wormwheel, and as the latter is driven at the sidereal rate, the graduations of the circle remain fixed in position with reference to the stars. The index for the sidereal circle being carried by arms attached to the polar axis, the task of setting the instrument to a new position in right ascension is thus greatly simplified as it is only necessary to release the clamp (described later) and turn the polar axis until the new right ascension is indicated by the reading of the sidereal circle, the wormwheel and circle continuing their motion at the sidereal rate in the meantime. This avoids the necessity for calculation of the new hour angle and results in a saving of time and effort that is a marked advantage in many ways.

The graduations on all the circles are made by lines of such width that, in connection with two auxiliary index marks, they form a sort of vernier and give sufficient accuracy in setting. In passing it may be noted that in an observatory where a larger instrument of similar design is in use, the elapsed time from the end of one observation to the beginning of another, including change in setting, is very often less than two minutes.

Quick motion is obtained through the large helical gear which is keyed to the axis. The pinion driving this gear is mounted on ball bearings and connected to the driving shaft by a toothed clutch. When the clutch is released the gear may readily drive the pinion, a condition that exists when the slow motion is in operation.

Slow motion is obtained through a large wormwheel (the teeth are covered by a brass strip and hence do not show in the illustration), motion being derived directly from the driving clock in a manner described later.

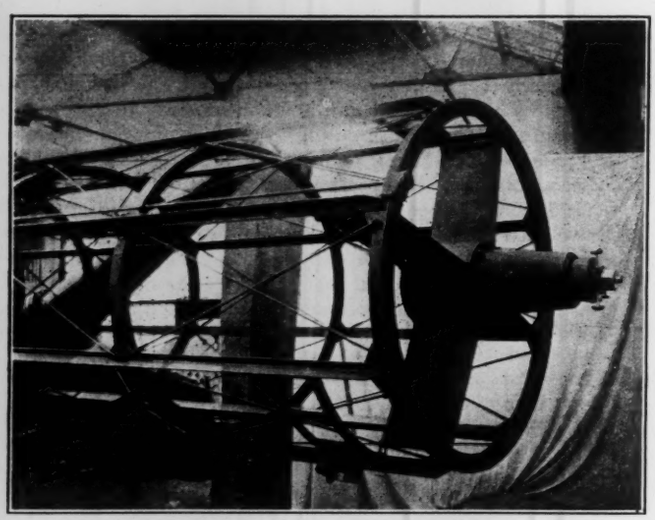

FIG. 7 VIEW OF UPPER END OF TUBE ARRANGED FOR PRIME-FOCUS WORK. EYEPIECE AND ADJUSTER SHOWN IN EXTENSION ADAPTER

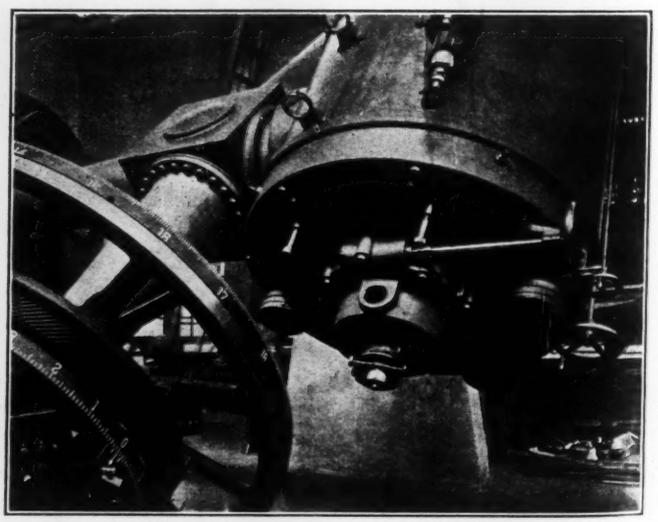

FIG. 8 VIEW OF LOWER SIDE OF MIRROR CELL WITH EYEPIECE AND ADJUSTER IN LOCATION FOR OBSERVATION WITH CASSEGRAIN COMBINATION

THE DECLINATION AXIS

We have already described the means by which the telescope tube is moved from east to west. For the north-and-south direction it swings on the declination axis, which is a massive steel shaft with flanged end bolted firmly to a tapered seat in the center piece of the tube. This shaft passes through the center or cubical section of the polar axis at exact right angles to the latter's center line and rotates in ball bearings. The power for movements in these coördinates is supplied by an electric motor with reduction mechanism, including a heavy wormwheel with bronze rim contained in the large housing at the outer end of the declination axis. The primary function of this great housing is to support the mechanism that provides the declination motion, but it also serves to counterbalance the weight of the telescope tube on the opposite side of the polar axis. This element of balance is extremely important and must therefore be subject to variation since various types of auxiliary apparatus are used from time to time on the tube. Whenever such auxiliary parts are attached, a corresponding weight may if necessary be added to the declination housing to keep the mass in perfect balance—although, as has already been noted, the balance of the instrument is such that a change in weights will seldom be be necessary. The large circle mounted on the declination axis just outside the housing is graduated to degrees and shows the angular distance of an object north or south of the celestial equator, the "declination" thus corresponding to latitude on the earth.

THE DRIVING CLOCK

Contrary to the popular impression, the stars do not travel across the heavens but the earth rotates about its axis, causing this effect. To compensate for this apparent motion a driving element must be provided which will keep the star constantly in the center of the field of vision of the telescope. Repeated efforts have been made for many years to use electric motors for this function. While partial success has attended some of these efforts, variations in speed due to changes in both voltage and temperature have defeated its successful application. Accordingly all large telescopes are driven by a clockwork mechanism commonly called the "driving clock." The driving clock in this telescope is shown in Fig. 3. The conical pendulum visible in the lower part of the clock case is mounted isochronously, that is, the speed of revolution is independent of the position of the balls within certain limits. This permits the adjustment of the pendulum so as to compensate for a considerable variation in driving torque with only a momentary and hence imperceptible deviation from a given speed. The main driving worm is mounted directly on top of the clock housing and is driven at the rate of one revolution every two minutes. This worm meshes with a very accurately cut bronze wormwheel, mounted on ball bearings at the lower end of the polar axis. This wheel revolves freely on the polar axis, clamped in the manner which is described later in this article. The reason for designing the driving element to permit the large wormwheel to revolve freely as just described, is to facilitate the rapid changing of the telescope from one star to another without the necessity for stopping the driving clock. In other words, once started, the driving clock is allowed to run throughout the observing period, and the clamping mechanism is employed in much the same manner as the clutch of an automobile.

A separate motor is located in the base of the clock which transmits power through a worm gear and a vertical shaft to an independent spiral pinion also mounted on top of the clock housing. This pinion meshes with a corresponding spiral gear, 6 ft. in diameter, which is keyed to the polar axis somewhat below the main wormwheel described above. It is this mechanism which affords the astronomer a means of changing his telescope rapidly to another position in the heavens. But the speed of this quick-motion mechanism is such that the observer may not be able to locate his star in the center of his field with the required accuracy. Accordingly two speeds faster than the sidereal rate and two speeds slower are provided to enable him to train his telescope exactly on the object to be photographed. A third motor is provided also in the lower portion of the clock housing which operates through differentials in the clock gearing and either advances or retards the speed of the main driving worm without affecting in any manner the rate of the conical pendulum. It merely increases or decreases the speed of the mechanism from the differential upward to the main wormwheel. When the desired object is located in the center of the photographic plate the differentials are cut out and the main driving worm assumes its regular or sidereal rate.

Automatic winding of the clock is accomplished by a separate electric motor which is cut in and cut out by switches that come in contact with the weight cable at either side of the rope drum. The gearing between the rope drum and the winding shaft is so arranged that the winding of the clock does not interfere with its driving rate, hence it is unnecessary for the observer to pay any attention to the clock throughout the observing period. Means are also provided for winding by hand in case of emergency.

ELECTRIC CONTROL

Mention has already been made of the four motors that actuate the telescope and wind the driving clock. With the exception of the winding motor, which is entirely automatic in its operation, the motors are handled by "remote control." The quick motions in right ascension and in declination, which are used when setting the telescope to any desired position, are controlled by master switches to be located on the west side of the south pier, from which position the astronomer can read all the graduated circles conveniently.

In operating the right-ascension quick motion, the first position of the master switch releases a clamp that connects the main driving wormwheel to the polar axis. This clamp consists of six pairs of levers mounted on the large spiral gear already mentioned and so arranged that powerful springs cause them to grip a finished flange that is attached to the wormwheel, the gripping surfaces being fitted with asbestos brake lining. The clamp is released by six solenoids which compress the springs enough to release the grip. To provide against possible failure of one pair of levers to release, each pair is arranged to close an electric contact when in the released position, and the circuit therefore is not complete until all have released. This circuit when closed energizes a clutch that connects the quick-motion pinion to the driving shaft, and motion of the telescope may then be obtained by holding the master switch in the second or running position.

Quick motion in declination is obtained in a similar manner, the clamp being replaced by a selective clutch in a speed-change gear box.

For a more accurate setting and guiding of the instrument portable push-button stations are provided in order that the astronomer may have complete control of the motion of the instrument at his finger tips. These stations consist of two small aluminum boxes connected by flexible cable to the upper and lower ends of the telescope tube, respectively, and provided with loops for a belt. Each box contains six push buttons by means of which the instrument may be moved either way in either coördinate at either of two speeds. The right-ascension control is obtained from a pair of solenoids and a motor in the clock, operating through clutches and differential gearing already mentioned. The declination motions are obtained through the selective clutches and speed-change gear box used also for the quick motion.

All the wiring is brought to a service panel on the east side of the south pier. This panel carries the knife switches and fuses for the various motors and lighting circuits as well as the accelerating switches for the quick-motion motors. One of the features of this instrument is the entire absence of "arms" or "sectors" in connection with any of the driving mechanism in either coördinate. This simplifies the construction of the instrument and adds to convenience in using it, as it avoids the possibility of interruption due to having reached the limit of travel.

It is interesting at this point to direct attention to some of the outstanding features of the design of this instrument. Four electric motors only are employed to give all motions for the telescope already described, as well as to wind the clock. In telescopes of this size it has been customary to have many more motors. This practice has been improved in the present instrument by the ingenious use of differential gearing in the clock for the setting speeds.

The telescope tube presents a departure in design which enables the use of a much shorter overall length without reducing the focal length of the combinations employed. For observation in the prime-focus combination it is necessary to have a greater length of

(Continued on page 147)

Economy Characteristics of Stage Feedwater Heating by Extraction

By E. H. BROWN[1] and M. K. DREWRY,[2] MILWAUKEE, WIS.

Feedwater heating by extraction from the main unit, becoming increasingly important with rising steam pressures, complicates the computation of heat balance. The authors point out the influence of each possible factor in the computations, present a practical method for computing extraction cycles, and deal with various factors affecting turbine-room economy.

I—PRACTICAL COMPUTATION OF EXTRACTION CYCLES

NEGLECTING generator and mechanical losses when computing heat consumption in extraction feed-heating systems may result in an error of 0.5 per cent in overall turbine-room economy; ignoring the change in stage efficiencies may amount to nearly the same error; or assuming no terminal difference at the heaters nor moderate pressure drops to them or at the extraction nozzles may cause errors of 0.6 per cent and 0.1 per cent each, respectively. Taking into account flashing of the drained condensate from heater to heater, as actually occurs, may preclude the occurrence of an error of $^3/_8$ per cent, and using manufacturers' guarantees instead of handbook values gives results 0.3 per cent nearer the correct value per 5 per cent error in steam rates when computing the net benefits of extraction.

All of these possible errors, obtained by computation of typical cycles, illustrate the necessity of understanding turbine-extraction and stage-heating characteristics when calculating feedwater-heating cycles. To make clear the principles used in this paper and in the method which it offers, a short illustrated discussion of the simple straight-line characteristics of turbines, telling of the relation of inlet and nozzle pressures and temperatures to total steam extracted and to load carried, has been included and may be found in a later section.

Method of Computing Cycles Outlined

Much has been published of the benefits of feedwater heating by stage extraction, but comparatively little has been written of how those benefits are computed. Since installations in different power stations are rarely identical, the necessity of calculating cycles for each plant is imperative if accurate results are to be expected. A comprehensive method, utilizing no gross approximations, which may apply at one plant and not at another, but which, nevertheless, must be simple, conducive of mathematical accuracy, and adaptable to all types of cycles, is needed.

A method developed in the offices of the company with which the authors are associated is thought to possess these qualifications. It has not been made empirical for the sake of brevity; it attacks all details of the problem and aims to attain simplicity and accuracy only by convenient and logical arrangement of the calculations.

Only three fundamental processes are necessary in computing feedwater-heating economies. They are:

a Determination of the heating value of the extracted steam
b Computation of the amount to extract
c Determination of the effect of extraction upon output and, consequently, upon economy.

Finding the heating value of the extracted steam and its effect in decreasing output (if no additional throttle steam is supplied) involves the use of an all-important tool in this work—the turbine expansion line as drawn upon a standard Mollier chart. From this simple line can be read directly the temperature, quality, total heat, and work done at any pressure in the machine and at any fractional load with an accuracy comparable to test accuracy.

Once the expansion line is obtained, feed-heating calculations are a matter of simple arithmetic, but the determination of this graph from the manufacturers' guarantees is more complex. The illustrative tabular form accompanying the method later described itemizes the calculations which must be performed, and a later paragraph tells in detail, for the benefit of those not closely acquainted with turbine practice, how stage efficiencies in various types of machines are varied. Fig. 1 shows typical expansion

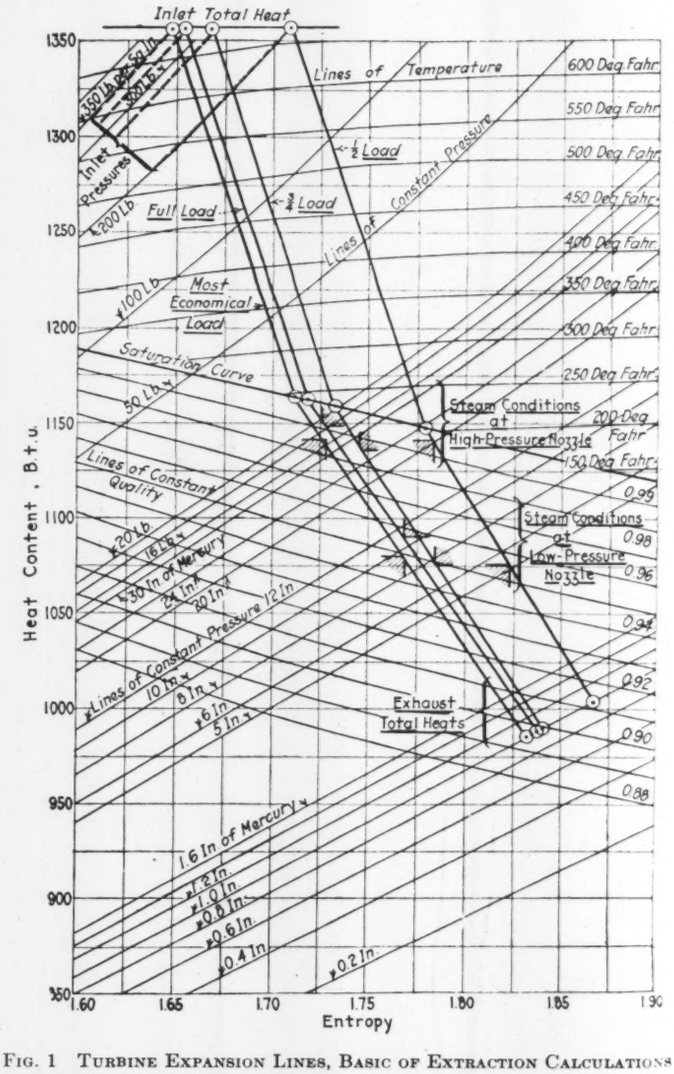

FIG. 1 TURBINE EXPANSION LINES, BASIC OF EXTRACTION CALCULATIONS

From these easily drawn lines, data for which are taken from the manufacturer's guarantees, may be read directly the quality, temperature, total heat or work done for steam extracted at any pressure, with accuracy comparable to test accuracy. All computations in this paper were based upon the above lines representing the expansion at nominal loads of a 20,000-kw. straight reaction turbine.

lines of a 20,000-kw. straight-reaction unit, upon which all computations in this paper are based.

Effect of Generator and Mechanical Losses Upon Computed Heat Consumption

Since the turbine expansion line, as drawn upon a Mollier chart, is the basic tool with which the calculator of extraction economies works, its determination with fair accuracy is important.

The expansion line represents conditions as they occur inside the turbine casing; it is concerned with generator efficiencies and mechanical losses only so far as they furnish a means of cor-

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Contributed by the Power Division and presented at the Annual Meeting, December 3 to 6, 1923, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. All papers are subject to revision.

recting manufacturers' guarantees to give the "internal" efficiencies and conditions. Obviously to charge the exhaust steam with greater heat than it actually possesses because generator or bearing losses are not taken into consideration, is a gross error.

Generator efficiencies form the greater portion of external losses, and if not determined from the manufacturers' guarantees must be estimated before the turbine expansion line can be drawn. Economics should determine an expression for the electrical efficiency of various-sized units, but unfortunately no simple relation can be derived which will accurately express generator losses as a function of capacity, load, and speed. Omitting speed and other variables, the efficiencies at fractional loads of representative-sized generators used in extraction feed-heating installations are approximately represented by the empirical equation:

$$\text{Efficiency} = 0.98 - \frac{0.055}{\sqrt[3]{\frac{\text{Kw. Rating}}{1000}}} \times \frac{\text{Rating}}{\text{Load}}$$

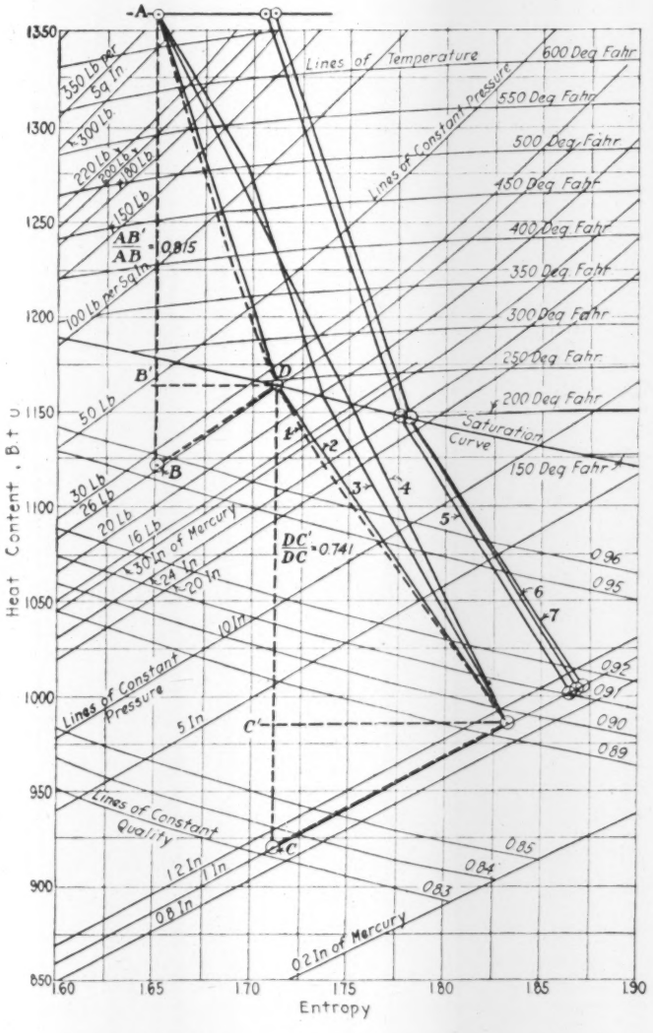


FIG. 2 VARIOUS TYPES OF EXPANSION LINES

Line 1—Test characteristics of the straight reaction-type turbine.
Line 2—Easily drawn straight-line expansion approximating line 1, by showing 10 per cent greater efficiency in superheat field than in saturated field, gives data of high accuracy for feedwater-heating calculations.
Line 3—Estimated expansion line of a combination velocity-compounded impulse and reaction turbine.
Line 4—Approximate expansion in a straight impulse machine, velocity-compounded in high-pressure blading and pressure-compounded in exhaust.
Line 5—Half-load expansion when extracting 15 per cent steam from a straight reaction turbine not previously proportioned by the manufacturer for extraction. Inlet pressure has been increased 10 lb. above the normal non-extraction value.
Line 6—Half-load expansion when extracting steam from a unit proportioned by the manufacturer for the given percentage of extraction. Inlet pressure is identical with the value upon which the guarantees are based.
Line 7—Expansion line when not extracting. Separation from line 6 near exhaust is due to decrease in leaving losses resulting from extraction.

Mechanical losses, which include bearing friction and gland and pump resistance, vary, as do electrical losses, as some odd function of the size of the unit. A rough rule of thumb which may be used for feedwater-heating calculations states that mechanical losses in percentage of normal rating equal at full load

$$\frac{4.0}{\sqrt{\frac{\text{Kw. Rating}}{1000}}}$$

For a 3000-kw. machine the losses computed by this formula aggregate about 2 per cent of the normal rating; for a 30,000-kw. unit they total 0.7 per cent. In any event the absolute error in finding these small friction quantities is trifling, and when applied to extraction calculations the possible discrepancy will be diminished to minute amounts.

USE OF NON-EXTRACTION EXPANSION LINES TO DETERMINE EXTRACTION DATA

As previously stated, expansion lines are drawn from manufacturers' guarantees, though these performances represent non-extraction operation. The application is not strictly correct; however, it causes an error which is probably not discoverable by even extremely accurate computation.

At present, when the manufacturer is asked to supply estimates upon an extraction installation, he gives non-extraction steam rates upon a machine which is necessarily of smaller turbine capacity than the machine which he would finally provide. For a given unit the most economical load position, which is determined by the amount of steam that can be passed through the machine without admitting steam at lower stages or opening up additional nozzles, differs when extracting various amounts of steam, and as a result the manufacturer must estimate upon a fictitious unit in order that his guarantees may be representative of consumptions under actual extraction operation and that the most economical load point may occur at the specified load. Therefore expansion lines based upon such steam rates are identical in position and length for both extraction and non-extraction operations.

Machines not proportioned for extraction, to carry a given load when extracting, must have greater inlet pressure than the designed values, for greater weights of steam must be passed at that load. Common practice states that for every pound extracted a given fraction of a pound must be added at the throttle, but at best the rule is a gross approximation if applied indiscriminately to all nozzles. The expansion line for extraction operation of a unit not designed for extraction is represented by line 5, Fig. 2. Apparently the line differs from the non-extraction one only in position and length, and though practically it does not change the accuracy of the data which it furnishes, it does represent a change in the output for a given amount of steam. In the method of computing entire cycles later described, the method of allowing for this effect upon output will be indicated.

Extracting steam at large loads decreases leaving losses from the exhaust blading, for less steam passes through the last rows—with consequent lower velocities. Good practice in large installations requires less than two per cent leaving loss at full load and 1.5 per cent at most economical load, though at 100 per cent power-factor overloads or in small units exhausting into high vacuums this percentage should be raised considerably.

A secondary effect of decreasing exhaust steam by extraction is the slight increase in vacuum resulting when less exhaust heat is absorbed by constant quantities of cooling water and at constant temperatures. The economy will vary considerably with different installations, and only the use of vacuum-correction curves for the particular turbine and vacuum-versus-total-steam curves for the condenser, which may be obtained from the manufacturer, will indicate the results. For an average installation the decrease in heat consumption due to increase in vacuum resulting from extraction is estimated at 0.25 per cent. Another and probably better method of estimating the gain due to having less steam pass to the condenser, is to consider the decrease in cost of providing a smaller condenser. On a cost basis the economy is 3 per cent of the initial condenser purchase price for typical equipment and extraction practice.

INFLUENCE OF STAGE EFFICIENCY AS REPRESENTED BY THE EXPANSION LINE UPON ACCURACY OF FEEDWATER-HEATING CALCULATIONS

That the easily drawn straight-line expansion line, broken to represent approximate relative efficiencies of the high- and low-pressure stages, is fully accurate enough for the most exacting of feedwater-heating calculations, has been definitely demonstrated by a considerable number of comparative computations.

Error in estimating the overall efficiency of the unit when drawing expansion lines results in a maximum extraction-gain error due to inaccuracy of heating calculations of $^1/_{16}$ of one per cent per 1 per cent error in efficiency ratio. The error decreases to $^1/_{40}$ per cent as the efficiency ratio decreases from 90 per cent to 65 per cent. The importance of correcting the manufacturers' guarantees for bearing friction, and of knowing generator efficiencies accurately, is therefore not great, and either values may be estimated if extreme accuracy is not desired. Both corrections, however, are quite accurately made in obtaining internal efficiencies by the method later demonstrated.

COMPUTATION OF FEEDWATER HEATING CYCLE

Steam Conditions:- 380 lb. gage; 250 deg. fahr.; 29 in. vacuum
Equipment in Cycle:- Two heaters

		Fractional Load				High-Pressure Heater, Approx. Fractional Loads			Low-Pressure Heater, Approx. Fractional Loads		
Non-Extracting Operation		1/2	3/4	M.E.	Full	1/2	3/4	M.E.	1/2	3/4	M.E.
1	Output, kw. ..... (given)	10,000	15,000	18,680	20,000	..	..	..	..	..	..
2	Steam Rate, lb. per kw-hr. ..... (given)	10.18	9.65	9.53	9.57	..	..	..	..	..	..
3	Total Steam, lb. per hr. (No. 1 × No. 2)	101,800	144,800	178,000	191,400	..	..	..	..	..	..
4	Generator Efficiency ..... (given)	0.948	0.960	0.964	0.966	..	..	..	..	..	..
5	Brake Horsepower Output [No. 1 ÷ (No. 4 × 0.746)] .	14,120	20,920	26,000	27,750	..	..	..	..	..	..
6	Total Heat at Throttle, B.t.u.per lb.(From steam table)	1356.5	1356.5	1356.5	1356.5	..	..	..	..	..	..
7	Work Done, B.t.u. per lb. [(No. 5 × 2545 ÷ No. 3) + % for friction]	353	368	372	369	..	..	..	..	..	..
8	Total Heat at Exhaust, B.t.u. per lb. (No.6 minus No.7)	1003.5	988.5	984.5	987.5	..	..	..	..	..	..
9	Heat of Liquid at Hotwell, B.t.u. per lb. (Steam table)	47	47	47	47	..	..	..	..	..	..
10	Heat Supplied by Boiler, B.t.u.per lb.(No.6 minus No.9)	1309.5	1309.5	1309.5	1309.5	..	..	..	..	..	..
11	Heat Consumption, B.t.u. per kw-hr. (No. 2 × No. 10) ..	13,331	12,637	12,482	12,533	..	..	..	..	..	..
12	Inlet Pressure, lb.abs. (M.E. and full-load values = throttle pr. abs. - 5% and 7% resp.; 1/2 and 3/4 load values are proportional to No. 3,M.E.load)	200	284	350	340	..	..	..	..	..	..
Extracting Operation											
13	Pressure at Nozzle, lb. abs. (M.E.load value given; others proportional to No. 3).....					10.05	14.3	17.4	2.81	4.0	4.9
14	Pressure at Heater, lb. abs. (No. 13 minus 5% pipe drop and 2% extraction drop at h.-p. nozzles; 5% extraction drop at l.-p. nozzles)					9.35	13.3	16.2	2.53	3.6	4.4
15	Saturation temperature at Heater Pressure, deg. fahr. (From steam table)					190	207	217	135	149	157
16	Final Feedwater Temperature [No. 15 minus terminal difference (7 deg.)]					183	200	210	128	142	150
17	Heat of Liquid of No. 16, ...					151	168	178	96	110	118
18	Heat Supplied by Boiler, B.t.u. per lb. [No. 6 minus No. 17 (for h.-p. heater only)].....					1205.5	1188.5	1178.5	..	..	..
19	Total Heat at Nozzle, B.t.u. per lb. (From Mollier expansion lines)					1137	1137	1141	1076	1076	1079
20	Total Heat at Exhaust, B.t.u. per lb. (No. 8)					1003.5	988.5	984.5	1003.5	988.5	984.5
21	B.t.u. per lb. Work Lost in Extracted Steam (No.19 minus No. 20)					133.5	148.5	156.5	72.5	87.5	94.5
22	Kw-hr. Work Lost per 1000 lb. per hr. of Steam Extracted $\left(\frac{\text{No. 21} \times \text{No. 4} \times 1000}{3416}\right)$					37.0	41.7	44.3	20.1	24.6	26.7
23	Total Heat of Steam at Each Heater, B.t.u. per lb. (No. 19 minus radiation losses)					1137	1137	1141	1079	1076	1076
24	Heat of Liquid of Steam at Each Heater, B.t.u. per lb. [No. 17 + term. diff. (7°); for l.-p. htr., No. 9]					158	175	185	47	47	47
25	Heat Available for Heating Feedwater, B.t.u. per lb. (No. 23 — No. 24)					979	962	956	1032	1029	1029
26	Final Temperature of Feedwater, deg. fahr. (No. 16)					183	200	210	128	142	150
27	Initial Temperature of Feedwater, deg. fahr. (No. 26 of lower-pressure heater)					128	142	150	79	79	79
28	Temperature Rise of Feedwater, deg. fahr. (No. 26 minus No. 27)					55	58	60	49	63	71
29	Quantity of Feedwater, lb. per hr. [No. 3 (except for l.-p. heater = No. 3 minus sum of No. 33 for all higher-pressure heaters.]					101,800	144,800	178,000	96,120	136,140	166,910
30	Heat Transferred to Feedwater, million B.t.u. per hr. (No. 28 × No. 29 ÷ 10^6)					5.6	8.4	10.68	4.72	8.57	11.84
31	Heat Flashed into Heater by Drained Condensate, million B.t.u. per hr. (No. 28 × sum of No. 33 of all higher-pressure heaters)					..	..	..	0.31	0.50	0.66
32	Net Heat Supplied by Extracted Steam, million B.t.u. per hr. (No. 30 minus No. 31) ...					5.6	8.4	10.68	4.41	8.07	11.18
33	Weight of Steam Extracted, lb. per hr. [No. 32 × 10^6) ÷ No. 25]					5,720	8,720	11,170	4,280	7,850	10,870
34	Kw. Work Lost in Extracted Steam, kw-hr. (No. 33 ÷ 1000 × No. 22)					211	364	495	86	193	290
35	Total Kw. Decrease in Output, kw-hr. (Sum of No. 34 for all heaters)					297	557	785	..	..	..
36	Kw. Output Extracting (No. 1 minus No. 35)					9,703	14,443	17,894	..	..	..
37	Per Cent Decrease in Output when Extracting (No. 35 ÷ No. 1)					2.96	3.7	4.18	..	..	..
38	Steam Rate, lb. per kw-hr. (For exact fractional loads of units proportioned for extracting, No. 3 ÷ No. 36)					10.490	10.025	9.948	..	..	..
39	Steam Rate, lb. per kw-hr. (For non-proportioned units, from curve of No. 38 vs. No. 36 at exact fractional loads)					10.437	9.996	9.948	..	..	..
40	Heat Consumption, B.t.u. per kw-hr. (No.18 × No. 38 if extraction unit, No. 18 × No. 39 if not proportioned)					12,583	11,880	11,724	..	..	..
41	Weight Extracted, Fractional Loads, Each Heater, lb. per hr. (No. 33 + % given in No.37)					5,850	8,980	11,550	4,420	8,150	11,350
42	Weight Extracted, Fractional Loads, All Heaters, lb. per hr. (Sum of No. 41)					10,270	17,130	22,900	..	..	..
43	Total Steam, lb. per hr.					104,700	150,000	185.000	"	"	..

FIG. 3 SAMPLE CALCULATION OF A TWO-HEATER CYCLE

In making complete calculations, steam-jet air pumps, deaerators, evaporators, and steam-driven auxiliaries are given columns just as are the heaters.

DETAILS OF AUTHORS' METHOD OF COMPUTING CYCLES

Based upon the initial assumption that non-extraction total steam is passing through the turbine, the method considers the effect of extraction upon output and then later adjusts the results to full extraction operation at the even fractional loads. It may be considered as an estimate of temperatures, pressures, and quantities which would occur at every point of the cycle were tests made upon the turbine and its auxiliaries, first at normal loads with its extraction nozzles closed, then at decreased loads after the nozzles are opened, and finally at full loads again while still operating extracting.

As shown in the sample computed cycle, Fig. 3, the calculations are tabular, the first part being devoted to straight non-extracting operation and the latter to extraction. The functions of the entries in the columns will now be explained.

Non-extraction operation is useful in indicating the heating value of the extracted steam and the effect of its extraction upon output. Items 1 to 8 and item 12 give data for drawing expansion lines, for they determine exhaust and inlet points, which, when properly plotted and connected upon a Mollier chart, result in a curve telling the pressure, temperature, quality or superheat, and total heat of the steam at any point in the machine. Exhaust total heat is plotted on the 1-in. absolute-pressure line, the vacuum in this problem being 29 in., and inlet pressure is plotted upon the 1356.5 B.t.u. total-heat line.

Tests, supported by thermodynamic analysis, have shown straight reaction-type turbines to have 10 per cent greater efficiency in the superheat field than in the saturated area. To represent these test conditions a broken line connecting the inlet and exhaust points, and changing direction at the saturation line, serves very well. Actually the line should be curved, as shown in the figure, but such refinements for extraction calculations are unnecessary.

To draw lines representing the stated difference in efficiency ratio requires cut-and-dry approximations until the correct values are reached. For the initial trial, step off to the left of a straight line connecting inlet and exhaust points about an inch (on the full-sized Mollier chart)[1] on the saturation curve, and through that

[1] About $^5/_{16}$ in. on the reduced chart, Fig. 2.

point draw a temporary broken expansion line. The stage efficiency represented by each part of the line equals the work actually done in each stage (AB' and DC', respectively, in Fig. 2) divided by the work possible in a perfect turbine, represented by AB and DC, respectively. When the ratio of these two efficiencies equals 1.10 as in the figure shown, then the lines may be permanently drawn and used for obtaining extraction data.

Combination impulse and reaction machines have expansions appearing somewhat as is shown by curve 3, Fig. 2, due to the inherent inefficiency of the impulse element used. Unless the heat drop and efficiency of that element are known, an expansion line drawn as previously described but on the basis of 5 per cent efficiency difference in the superheat and saturated fields, is advised. Straight impulse-type machines, velocity-compounded in the high-pressure stages and pressure-compounded at the exhaust end, have more nearly a straight-line expansion characteristic and may be drawn as such, though of course manufacturers' test results should always be used in drawing expansion lines if available.

Items 9 to 11, inclusive, compute non-extracting heat consumption, which is useful in calculating the benefits due to extraction. Of course, the economies stated on the form are only turbine-room values. Overall plant economies are obtained by dividing by boiler-room efficiencies and taking into account consumption of auxiliaries and wastages.

Under the caption "Extracting Operation" the items may be divided into three sections. Items 13 to 25 give preliminary values which are later used in the actual cycle calculations. Items 26 to 36 solve for the decrease in output resulting from extraction. The remaining items give economies and quantities when full fractional loads are being carried. The notes after each entry, inserted for the purpose of expediting computation and diminishing chances of gross errors, show how the values are obtained.

Application of Method

In actual use, separate blueprints, photostats, or other reproductions of the tabular form Fig. 3 are pasted to the calculation pages and separate solutions made for each cycle.[1] Ordinary five-line-per-inch paper, properly ruled vertically for the specific cycle, is best for the calculations. With some experience, the calculations may be performed with great rapidity, many values being obtained without changing the slide-rule setting. Given only guarantees, generator efficiencies, and extraction-nozzle pressures, a representative two-heater cycle may be worked in two or three hours by any one slightly acquainted with the work.

Slide-rule accuracy is fully accurate enough for the most exacting requirements in all except two items, items 38 and 40. In making the division for item 38 and the multiplication for item 40, solution by comptometer, long-hand, or a combination of longhand and slide rule is necessary if accuracy greater than 0.1 per cent is desired.

Solution of cycles containing steam-jet air pumps, deaerators, evaporators, steam pumps or other auxiliary equipment does not lessen the value of the tabular form, for this equipment is given columns in the calculations just as are the heaters. The solution is in the opposite direction, however, since total steam to the added equipment is known and temperature rise is desired. Therefore the calculations are performed by working from item 33 upward to item 26, instead of downward as in heater calculations. Of course, the terminology of some of the items must be mentally broadened to apply to all types of equipment. Cycles containing desuperheaters are computed in a manner no different than are systems without that equipment, though of course item 43 must be increased by the amount of injection water if such is supplied from an external source. If evaporation of make-up water is intermittent, occurring only at periods of low loads and storing for full loads, as seems advisable practice in future designs, then the calculation of evaporators should be applied only at fractional loads.

Allowance for power to drive electrical auxiliaries, if that power is taken from the main unit, may be made in item 35 so that exact nominal loads at either switchboard or main bus will be obtained in the correction curve of item 39. Since full rated load (20,000 kw. in the example cited) is not obtainable on the main bus when furnishing auxiliary load without carrying a generator overload, the full-load entry must be made with power-factor qualifications.

For computing comparative cycles, as is done in power-plant design, the method is flexible in that it does not involve the derivation of separate formulas for each cycle as is necessary if accuracy is desired when using the formula methods. Provided a formula is used a great many times and the computer is acquainted with its notation, then it possibly is a labor-saving device.

[1] A limited number of sample forms for computing the feedwater heating cycle as in Fig. 3 are available and may be procured upon application to the Secretary of the Society, 29 W. 39th St., New York.

II—MAXIMUM REALIZATION OF EXTRACTION GAINS

Effect of Relative Position of Heater Upon Economy of Feedwater Heating

For this study a representative cycle of two heaters, heating to 210 deg. fahr. at most economical load, was initially chosen. The low-pressure heater was varied in position from 25 per cent to 87 per cent of the heat-drop interval between the high-pressure heater and the exhaust, and the resulting economies figured.

Fig. 4 shows that best economy is obtained when operating

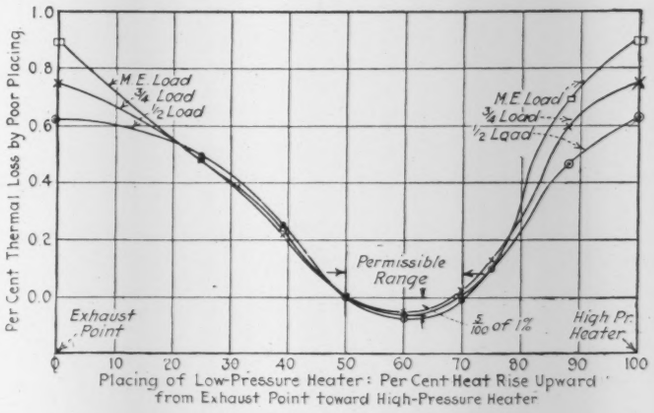


FIG. 4 BEST THERMODYNAMIC PLACING OF HEATERS

Calculations of complete cycles show that for best economy with two-heater cycles the lower heater should do approximately 60 per cent of the feedwater heating. For multi-heater systems the lower-pressure heaters should carry slightly more of the heat load than the upper ones, though accurate placing is not thermally important.

with the low-pressure heater at a point 60 per cent of the heat-drop interval upward from the exhaust, or in this case at a pressure of about 4 lb. per sq. in. absolute. Under these conditions slightly more heat is transferred in the low-pressure heater, though considerably more power is lost in steam extracted from the high-pressure nozzle. Accurate placing of heaters is not of importance, for, as the curve shows, any position from 50 to 70 per cent of the heat drop causes a change in economy no greater than $^1/_{20}$ of 1 per cent. In three- or four-heater cycles slight preference should be given low-pressure heaters in distributing the heat loads, working the high-pressure ones at lighter values, though this adjustment is not strictly necessary. In computing two three-heater cycles having the ratio of heat absorbed in each heater, starting with the high-pressure heater in each case, 1.0–1.6–1.1 and 1.0–0.97–1.8, respectively, a difference in heat consumption of the order of $^1/_{100}$ per cent was found.

Influence of Auxiliary Equipment upon Extraction Economy

A representative two-heater cycle, heating to 210 deg. fahr. at most economical load and containing a steam-jet air pump, showed increases of 1.1 per cent, 0.84 per cent, and 0.71 per cent in heat consumption at $^1/_2$, $^3/_4$, and most economical loads, respectively, above the same cycle computed without an air pump. True, average steam consumption of the air pump (0.8 per cent of full-load throttle total steam) heated the feedwater as much as 15 deg. fahr., but this being done at an extremely low temperature level by high-temperature-level steam resulted in decreasing the benefits of extraction heating from, for example, say, 5.5 per cent to 4.5 per cent. The fallacy of the time-worn expression crediting steam-jet air pump, injector, and other steam auxiliary equipment

in power stations with 100 per cent efficiency is thus strikingly indicated.

Were two-stage steam-jet air pump equipment so constructed that an extraction heater could be interposed between the two effects, these losses could be lessened to 0.96 per cent, 0.725 per cent, and 0.64 per cent, since most of the air-pump aftercooler heating could be done at a higher temperature level. If mechanically practical and fully as reliable as the steam-jet air pump, economical motor-driven vacuum pumps, with air pumps in reserve as "augmenters" or as auxiliaries when starting, would be desirable equipment, though continuity of service is of great importance in this consideration.

Effect of Type of Turbine upon Extraction Gains

Since extraction gains are caused by obtaining work from the extracted steam before it passes to the heater, the amount of work done in the machine down to a given pressure is a criterion of extraction efficiency. Machines with inherently inefficient high-pressure stages are at a disadvantage, therefore, in producing economy in extraction feed-heating systems. Expansion lines 3 and 4, Fig. 2, when used in giving data for a two-heater cycle heating to 210 deg. fahr. at the most economical load, give results 0.24 per cent and 0.325 per cent, respectively, poorer in heat consumption than curve 2. The latter has high-efficiency high-pressure blading and moderate-efficiency low-pressure blading; the former, to indicate comparable overall efficiencies, must have very high-efficiency low-pressure blading to counteract inevitable losses of the high-pressure blading. The extracted steam experiences these losses, but leaves the machine too early to compensate for them in the exhaust blading, with the net results that have been indicated above.

Due to the low temperature level of the heated generator air and bearing oil, their utilization for purely thermal considerations may be looked upon as questionable so long as feedwater is heated by stage extraction.

Comparative Economy of Stage Heating to Various Temperatures and with Different Numbers of Heaters

Allowing for terminal difference, extraction and pipe pressure drops, flashing, and using all refinements in cycle computations, representative systems heating to different maximum temperatures with one, two, three, and four heaters were accurately computed. In Fig. 5 the results are compared with heat consumption for non-extraction operation, though the curves afford intercomparison as well.

In agreement with previous published investigations, the curves show maximum benefits to occur at 245, 300, 320, and 330 deg. fahr. when heating with one-, two-, three-, and four-heater cycles, respectively. They also represent comparative economies in percentage of heat consumption at any final temperature and for any practical number of heaters. Fractional-load curves for the one- and two-heater cycles show the comparative economies at full and reduced loads, indicating maximum economy for all loads obtainable, not with constant feedwater temperature, but with changes just as they occur at extraction nozzles with variable loads, represented by the straight lines adjoining the calculated points in both systems. It will be appreciated that besides cutting the peaks of each set of curves, the straight lines AB and $A'B'$ also indicate the natural drop in temperature at the specific nozzle heating feedwater to those most efficient temperatures. Unless boiler-room practice rigidly requires constant feedwater temperatures at economizer inlets, the inherent simplicity of extraction stage heating can be maintained in the future.

Increase in the number of heaters, besides improving economy at any given final temperature and increasing the most economical temperature, broadens the range over which the system can operate without causing great decrease in economy. Three- and four-heater-cycle curves are appreciably flatter than those of fewer heater cycles. It will also be noted that the proportionate gain in installing additional heaters decreases rapidly, especially at the lower temperatures in use at the present time. Increase in final turbine-room feedwater temperatures, which is not unlikely, will increase the commercial advisability of providing greater numbers of heaters.

The Future of Stage Extraction for Feedwater Heating

That air preheaters can effectively lessen the economical rating of feedwater economizers, thus allowing greater benefits of extraction feedwater heating to accrue by heating to higher temperatures in the turbine room, seems probable. Mechanically and thermally successful air heaters have been tried and tested with creditable results, decreasing chimney temperatures to exceedingly low amounts while carrying part of the economizer heat loads. Increasing the turbine-room feedwater temperature to 300 deg. fahr. from the present practice of 210 deg. fahr. is therefore not improbable. The change would decrease economizer corrosion, increase boiler rating, and allow a gain in overall plant economy of a magnitude determinable by use of Fig. 5. The increase in feedwater temperature mentioned above would additionally improve turbine-room heat consumption 1.25 per cent if a two-heater system were in use; and 1.95 per cent for a three-heater system.

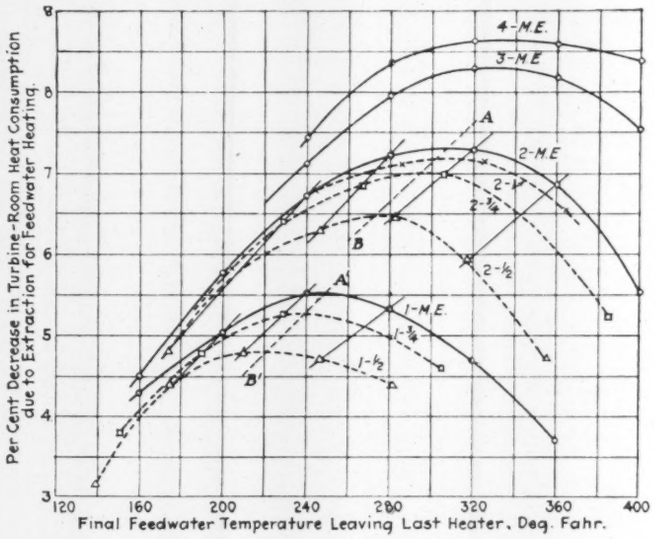


FIG. 5 PERCENTAGE OF HEAT SAVING EFFECTED BY EXTRACTION HEATING TO VARIOUS TEMPERATURES WITH DIFFERENT NUMBERS OF HEATERS, AS COMPARED WITH NON-FEED-HEATING OPERATION

Results of accurate computations of complete cycles, considering all extraction variables (with exception of leaving loss) in a typical installation, showing net and comparative turbine-room gains for a representative large-unit high-pressure machine, though applicable to others with small error. Curve 1-M.E. is for a one-heater cycle, most economical load; Curve 2¼ is for a two-heater cycle at three-quarter load, etc. Data from Fig. 1.

In smaller installations the plan of motorizing the auxiliaries, coupled with the inherent self-regulation of feedwater temperature in extraction systems, may render steam-turbine rooms more or less automatic in control. Auxiliaries can be permanently tied electrically to the main or auxiliary generator, gaining in speed with it when starting and being automatically shut down upon stopping. Feedwater heating by other means does not adapt itself to automatic control.

Larger installations with positive sources of current for auxiliary operation need maintain no inefficient steam-driven auxiliaries, with perhaps the exception of a few stand-by boiler-feed pumps, and thus may realize the full benefits of stage extraction. With the increasing interlinkage of power stations, steadier line conditions are assured, promising greater reliability of motorized auxiliaries in cases where auxiliary generators are not employed. By its nature, feedwater heating by stage extraction appears to adapt itself well to present power-plant practice, and continued adoption is anticipated.

Accuracy in extraction calculations can hardly be expected with the use of simple equations representing the involved internal characteristics of modern turbines. These characteristics must be understood, and for their expression the Mollier expansion line seems best suited. In calculating resulting heat consumption, allowance for all conditions in the cycle is demanded if accuracy commensurate with present requirements is desired. It is hoped that this paper may at least provide suggestions of some use to the producers of power.

Pressed-Metal Engineering

Diversity and Complexity of Process—Rapid Growth of Industry—Lack of Engineering Standards and Information—Possibilities and Limitations of Press Production—The Pressed-Metal Sales Engineer—Examples of Pressed-Metal Design

By DOUGLAS P. COOK,[1] WORCESTER, MASS.

PROBABLY no mechanical field of equivalent scope and importance in the business world of today so much needs and will so richly repay an unsparing critical analysis of its present status and conditions, as what has come to be known as the pressed-metal industry.

Broadly speaking, a thorough study of the application of press processes would cover three general producing groups: the so-called jobbing industry, comprising those plants that manufacture special pressed-metal parts to order; the several distinct industry groups that have gradually evolved as a result of intense specilization of the press process; and the difficult field of independent manufacturers of other than purely press products, who often devise and employ the most unusual and striking exemplifications of the process. In addition of course, there is the entire collateral field of pressed-metal equipment, which would require a history of its own.

Of this vast complicated category we are to consider briefly the present conditions and problems of one of the producing groups mentioned, the so-called "jobbing" pressed-metal industry, which is made up of about seventy-five major and about three hundred minor plants with an annual output having a value of probably forty to fifty million dollars.

The general technical history of the development of the pressed-metal process is probably too well known to require any detailed exposition. Its major claim to interest lies of course in its almost inconceivable diversity of application, with the inevitable result that no individual or no particular group of individuals can be said to be abreast of its progress. To one even casually informed, however, there is a whole realm of fascinating suggestion and business romance in considering the possibilities of a process so flexible and so controlled as to have pervaded ultimately hundreds of industries in countless forms and of the utmost variety and specialization of purpose.

Rapid Growth of the Industry

This very quality of flexibility of application, however, while exceedingly valuable to industry at large, has proved to contain both advantages and disadvantages to the jobbing industry. Primarily, it enabled the jobbing industry to attain the position of a major mechanical industry in a relatively short period of time. In spite of the constant defection of plants that had gradually developed some standard product and accordingly withdrew from general production, the ever-broadening possibilities of application supported the original companies and called new aspirants into the field. Thus the industry grew, perhaps more rapidly than it should, until today only the space of a single generation has elapsed from the earliest attempts at the simplest phases such as blanking, piercing, forming and later simple drawing of small ferrules, to the present complex development of amazing operations and massive equipment, producing intricate and hitherto undreamed-of shapes and sections.

But while this growth was relatively rapid, it was also as a result very uneven and almost uncontrolled. Except as occasionally large organizations called upon the process for some benefit collateral to its own process or purpose, there was no attempt to gather into one effective group with ample resources and far-sighted direction all of the then available and desirable knowledge of the developing art, with the purpose of guiding and assisting a rapid and broad expansion into all practical fields of application. It was left primarily to the jobbing industry alone, unaided by the usual benefits of organization or by the coöperation of collateral interests, to discover new fields and applications for the process, new outlets and markets for their products.

One of the three fundamental causes of what might almost be termed the lethargy of the industry in seeking to extend and stabilize its market, was in reality inherent in the peculiar empirical and individualistic method by which the industry has reached its present stage; of the remaining two, one, the contemporaneous growth of the automotive industry, was circumstantial, and the other, the effect of the war on the industry, historical.

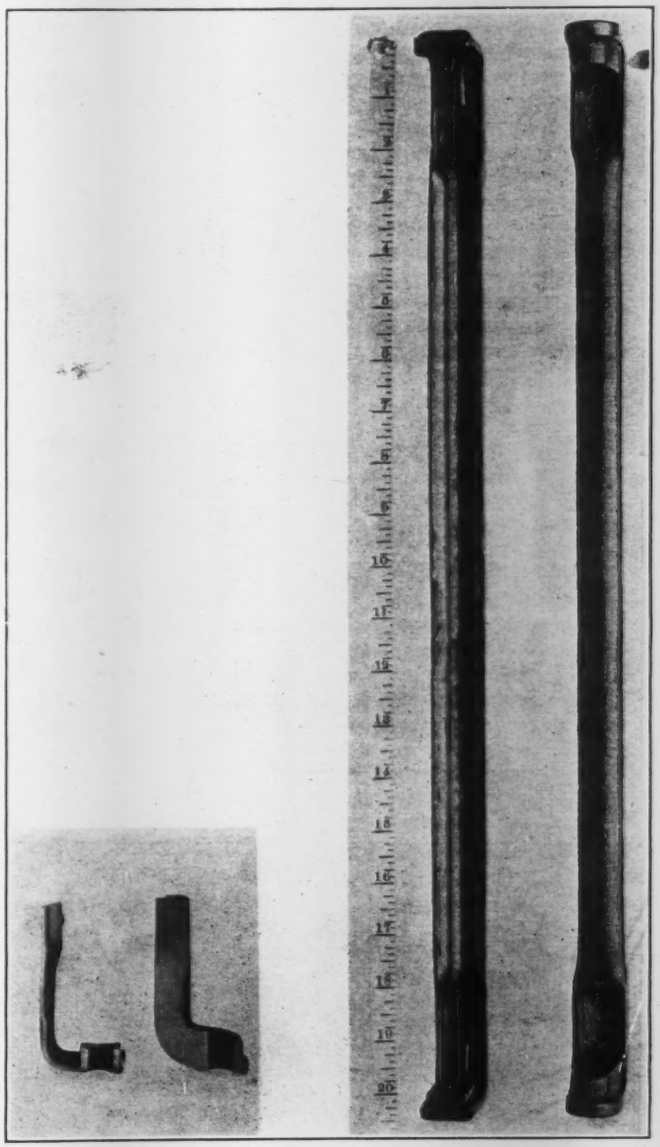


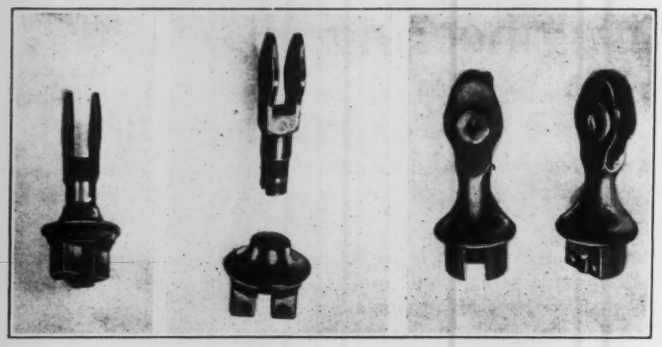
Fig. 1 Iron Casting to Pressed Metal. Cast-Iron Treadle Support for Sewing Machine

Special Problem: Elimination of brittleness to prevent breakage on export shipments.

Advantages of Pressed Metal: Elimination of brittleness; reduction of weight, 60 per cent; increased strength: Elimination of drilling and tapping; improved appearance—cheaper and better finish; slightly reduced cost. Note simple method of obtaining increased cross-section and tapped hole by inserting a standard punched nut

[1] President, Boston Pressed Metal Co.

Contributed by the Machine Shop Practice Division and presented at the Annual Meeting, December 3 to 6, 1923, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.



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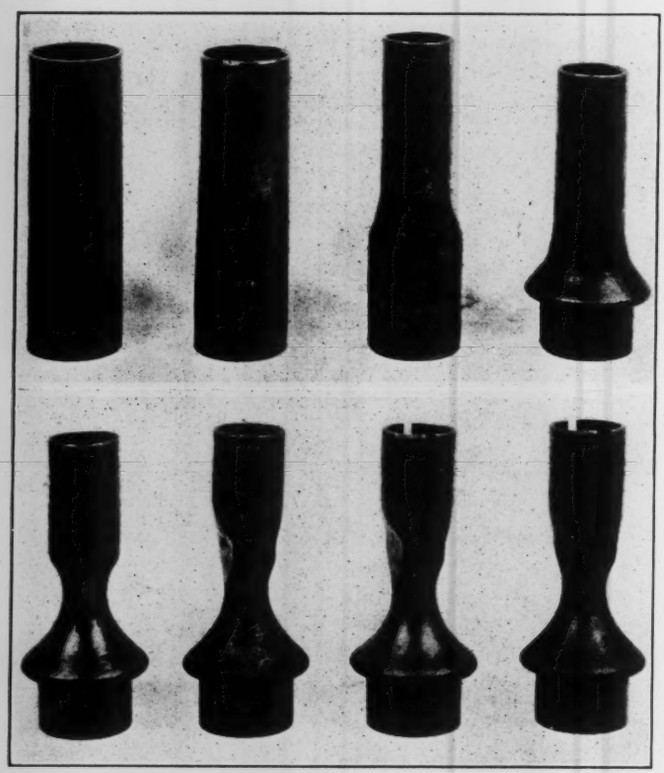

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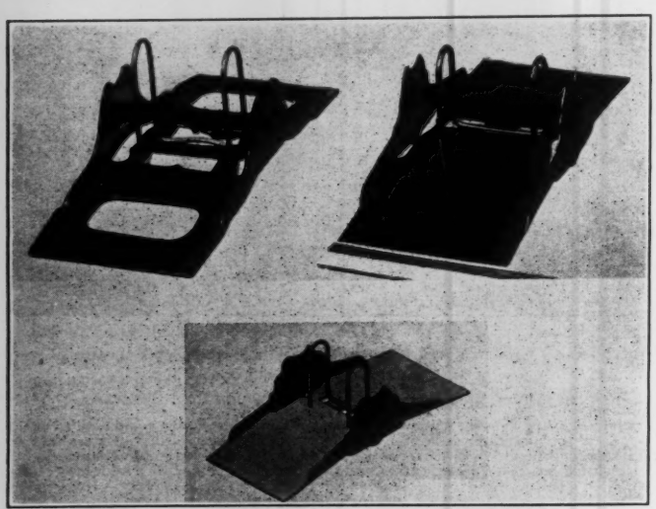

FIG. 2 IRON CASTING TO PRESSED METAL. CAST-IRON CALENDAR STAND

Showing original iron casting, hand model, and isometric sketch, Advantages of Pressed Metal: Reduction in weight, 40 per cent; reduction of transportation cost; elimination of brittleness; increased strength; uniformity; improved appearance and salability; reduction of finishing and final cost; greater possible variety of finishes.

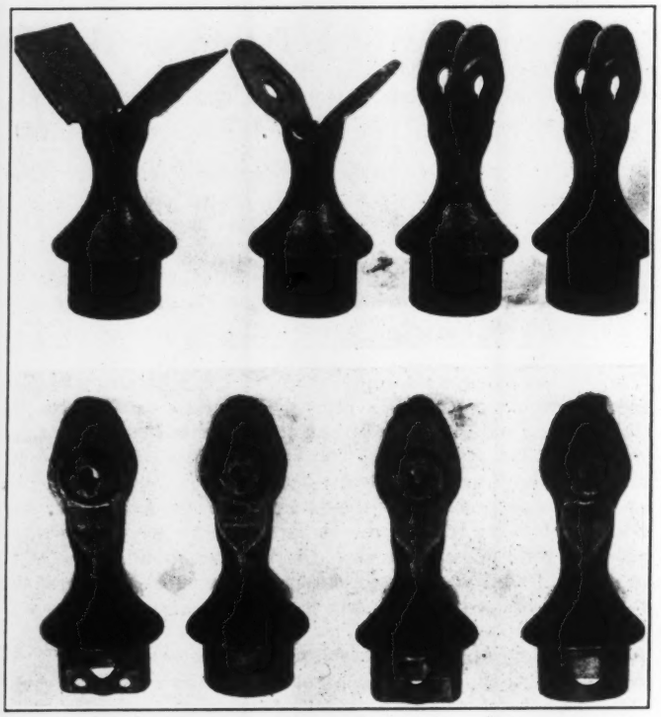

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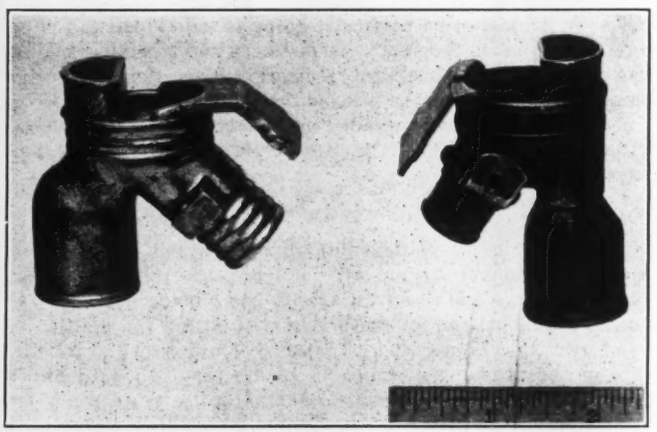
FIG. 3 IRON CASTING TO PRESSED METAL (STEEL). LUG HOLDER FOR TELEPHONE

Showing casting and finished redevelopment, and successive operation samples. Advantages of Pressed Metal: Reduction of cost, 20 per cent; reduction of weight, 63 per cent.



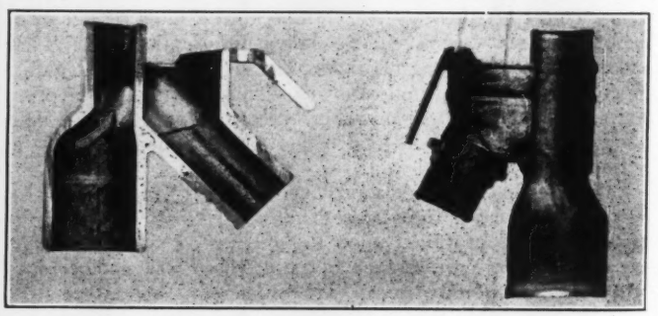


FIG. 4 DIE CASTING TO PRESSED METAL (BRASS). GAS-MASK FITTING

(Original die casting, pressed-metal assembly, and complete cross-section)

Special Problem: (1) Reduction of resistance to inhalation through mask without changing shape or outside dimension of fitting. (2) Elimination of dangerous blowholes in wall, sometimes impossible to detect.

Advantages of Pressed Metal: Reduction of resistance to inhalation about 87½ per cent; elimination of all blowholes and similar defects; greater strength; no increase in weight; elimination of brittleness; greatly increased productive capacity.

NOTE: Designed for U. S. Chemical Warfare Service to meet a special emergency during the war.

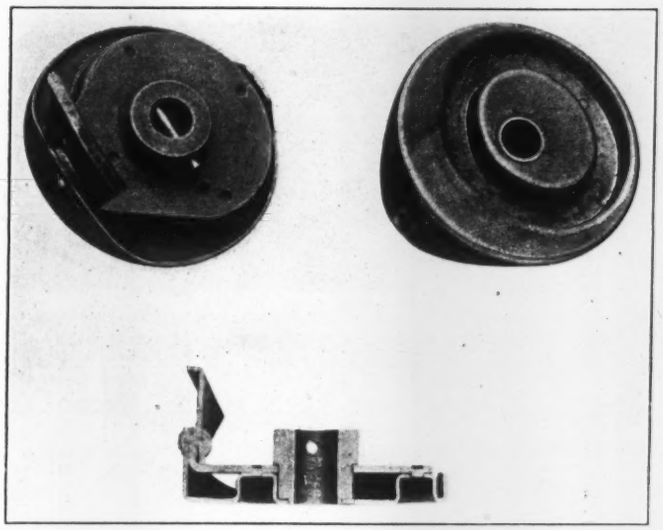


FIG. 5 IRON CASTING INTO PRESSED METAL ASSEMBLY. COMPOUND CAM

Showing redevelopment (front and back) and cross-section. Advantages of Pressed Metal: Reduced cost; increased production; decreased weight; elimination of machining. The redevelopment of this part from a cast-iron blank, machined, to a pressed-metal assembly with screw-machine bushing, saved approximately $3 each on a run of 5000 machines, or $15,000 clear saving and profit to the customer.

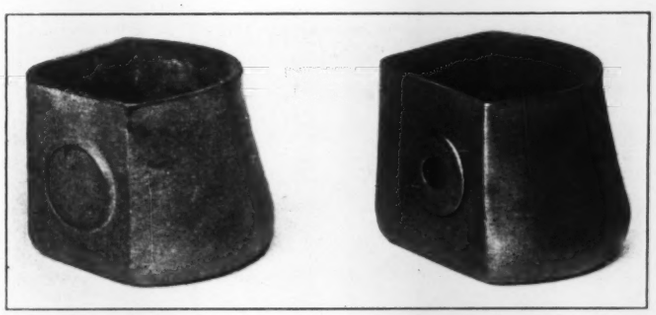


FIG. 6 ALUMINUM CASTING TO PRESSED METAL (BRASS). ASH BOWL

Advantages of Pressed Metal: Elimination of brittleness; reduction of finishing cost (polishing); increased strength, reduction of total cost; greater possible variety of finishes; elimination of machining operations; more durable finish and improved appearance.

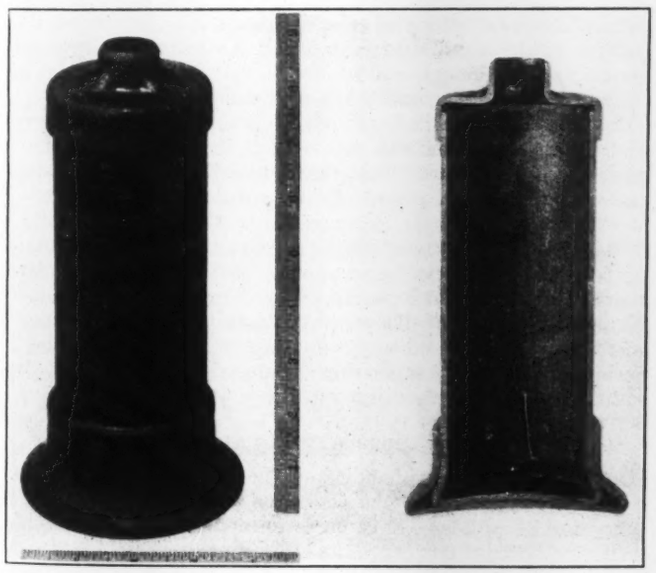
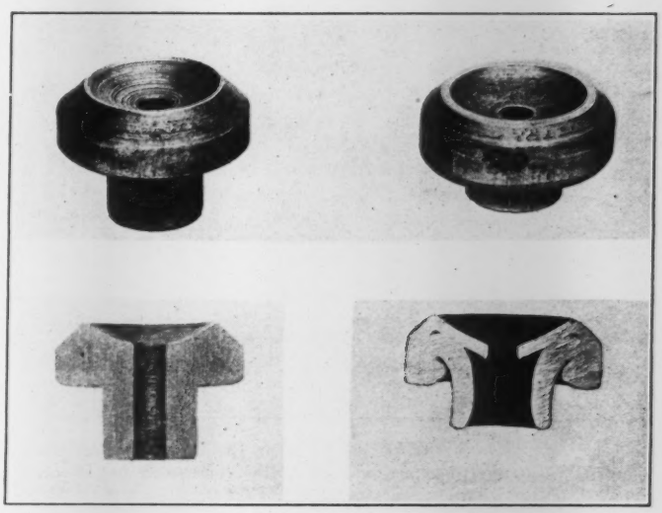


FIG. 7 SIMPLE ASSEMBLY (ORIGINAL DESIGN) IN PRESSED METAL ASSEMBLY FOR COMPRESSED-GAS (CO_2) AUTOMOBILE JACK

Advantages of Pressed Metal: Elimination of machining; strength and rigidity; economical production; simplicity of design; increased production. Note method of assembling cylinder and base by upsetting operation.



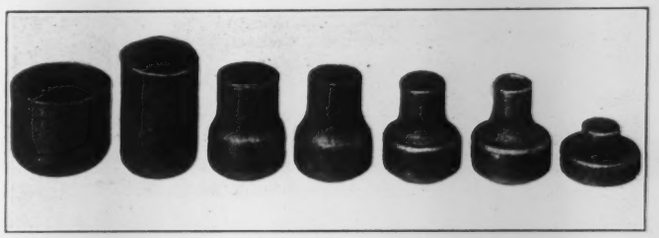


FIG. 8 SCREW-MACHINE PART TO PRESSED METAL (STEEL). BALL SEAT FOR DRAG LINK

Showing original part and redevelopment, comparative cross-sections, and successive operation samples. Advantages of Pressed Metal: Smoother seat for ball without secondary operation; increased productive capacity; decreased weight, 10 per cent; slightly decreased cost.

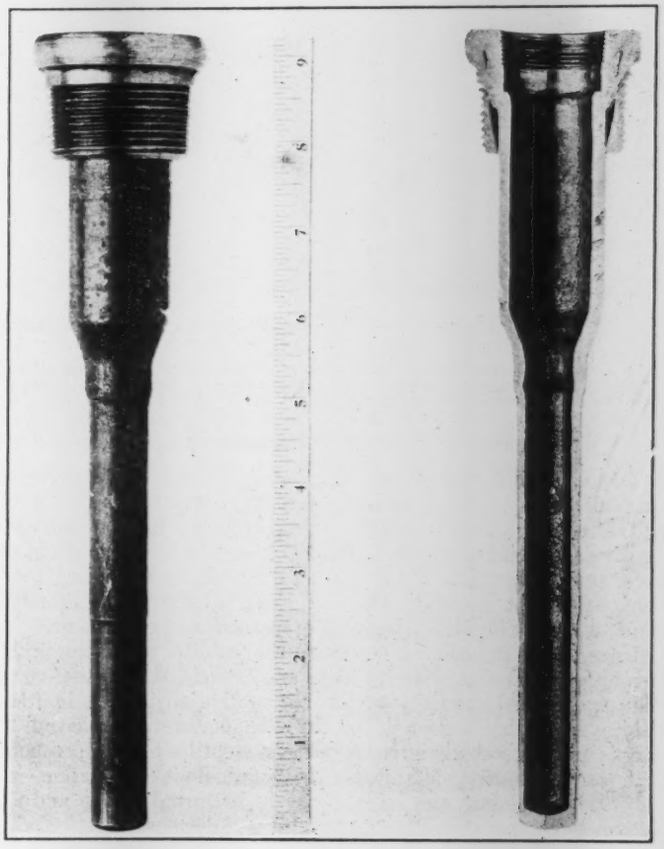


FIG. 9 SCREW-MACHINE PARTS TO PRESSED METAL (STEEL). EXPERIMENTAL DESIGN OF COMBINED BOOSTER AND ADAPTER FOR GAS SHELL

Illustrated primarily as a particularly fine example of deep drawing and cold forging. Observe the varying thickness of cross-section obtained and the heavy booster head formed by forging back flange.

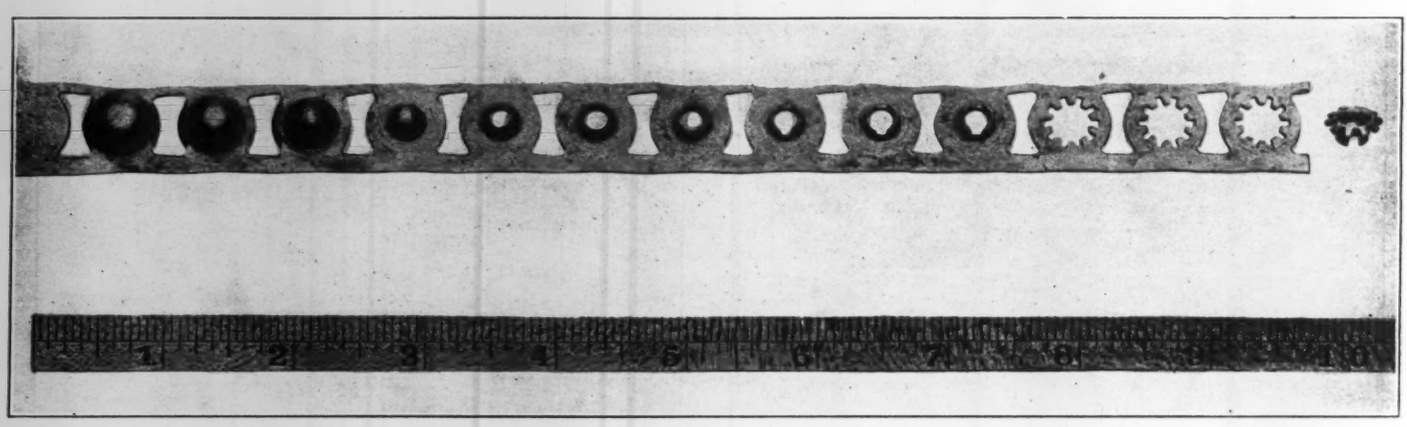


FIG. 10 ORIGINAL PRESSED-METAL DESIGN. SPEEDOMETER PINION

To illustrate method of combining operations whereby one piece and 15 operations are completed at each stroke of press. Progressive combination tools. Advantages of Pressed Metal: Elimination of all machining operation; greatly reduced cost.

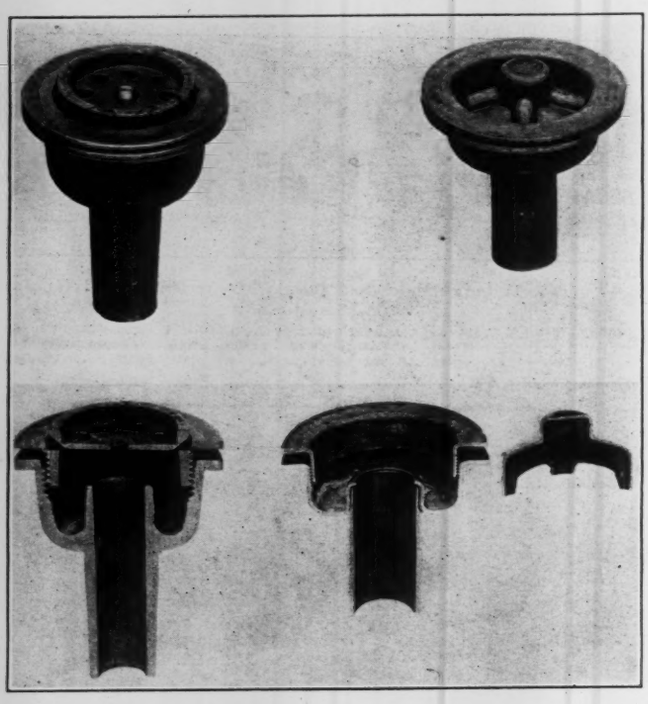


FIG. 11 SIMPLE ASSEMBLY, BRASS CASTING INTO ZINC. REFRIGERATOR-TRAP ASSEMBLY

Advantages of Pressed Metal: Reduction of weight, 60 per cent; decreased cost greatly improved function; inside smooth, easily cleaned, sanitary, less liable to clog; improved appearance and salability.

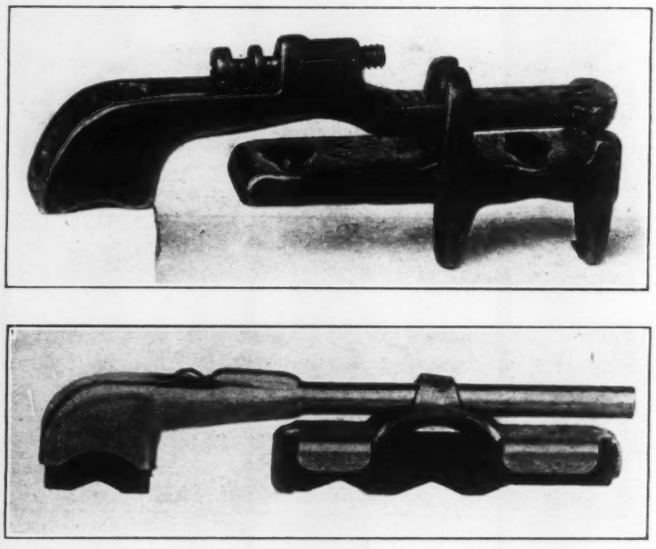


FIG. 12 SIMPLE ASSEMBLY INTO PRESSED METAL. TEXTILE-MACHINE PARTS

Showing original design and development. Advantages of Pressed Metal: Elimination of machining; simplification; elimination of parts; greatly decreased cost; improved function.

PRESSED METAL AND THE AUTOMOTIVE INDUSTRY

The vital and rapidly unfolding story of the contribution of pressed metal to the automotive industry, together with the resultant effect on both industries, would require a far more comprehensive study than can be attempted here, absorbing as it did an important proportion of the free and constantly expanding press capacity of the country, and supplying in return the principal impetus for the rapid development of methods and equipment.

Upon both industries, however, the results were practically revolutionary; progressing by leaps and bounds, the pressed-metal industry opened suddenly to the automotive engineer a limitless field, still but half-explored, for the manufacture of thousands of simple and increasingly intricate parts, susceptible of rapid, economical, large-quantity, interchangeable, close-limit production—resulting immediately and increasingly in improved design and appearance, greater strength, less weight, and decreased cost—a vital and indispensable contribution to the rapidly mounting automotive sales and production records of the last decade, without which the modern automobile would have been an impossibility.

To a considerable extent, and necessarily, this placed the industry in a position too wholly dependent upon its major customer whom it had primarily served, and this, together with a sometimes oversanguine and too rapid expansion, resulted inevitably in occasional oversupply, over-intense and unwise competition and uneven and unbalanced production, with all their attendant evils and ills.

The failure of the industry as a whole to apprehend the necessity of extending its foundations and markets in proportion to the expansion of its capabilities, was probably attributable to three major causes: the method of decentralizing growth; the absorption of all the existing group energy, so to speak, by the automotive and its allied industries; and the intense productive effort of the war period. Supplementary to these major causes, however, are a number of general conditions that strongly affect the status of the industry and seriously handicap its present efforts to adopt and practice generally the logical and seemingly imperative policy of sales expansion into relatively undeveloped industries, and a few of these conditions will be briefly discussed.

GENERAL LACK OF UNDERSTANDING ABOUT THE INDUSTRY

One exceedingly grave handicap is the total lack of any popular or general recognition of the enormous contribution that the industry and its processes have made to modern civilization, with a resulting absence of any consumer interest or support.

It is doubtful whether there is any industry or major process in modern business that has made a comparable contribution to the everyday life and convenience of the public, regarding which there is more ignorance and misconception than exists even today about the pressed-metal industry and the process of metal pressing. Few

recognize, for example, that a marvellous development of the industry—the making of cans and containers on intricate and highly specialized machines—created a whole industry and made possible the universal distribution of foods and fuels—meats, fish, fruits, vegetables, and oils—a service made inevitable and imperative by the concentration of urban population. Fewer still have any conception of entire industries based upon special applications of the press processes, and actually transformed and revolutionized by it—the manufacture of coffins, hollowware, the whole field of electrical and hardware accessories—through myriad ramifications into literally hundreds of industries.

LACK OF BROAD ENGINEERING STANDARDS AND INFORMATION

Almost as serious a handicap as the lack of consumer interest has resulted from the failure of the industry, or any part of it, to develop engineering standards or to publish adequate technical information for the assistance and guidance of possible customers. To a great degree the industry has been content to sit back and await customer inquiries, thus throwing upon the latter the necessity of developing his own conception of his requirements as to suitable design and requisite specifications, at the same time withholding from him the inestimable advantages of a careful, thorough engineering study of actual conditions and requirements that would lead to the most practicable and economical design.

The actual waste and wholly unnecessary confusion resulting from this blind and tacit acceptance of the customer's statements of requirements are simply appalling and are evidenced principally in three ways.

ERRONEOUS DESIGNS AND UNWISE SPECIFICATIONS

First, any customer, not minutely informed as to all the possibilities of his situation, may request quotations on some crude original design which perhaps may take but a fraction of all possible advantages of design or function that would have been disclosed by proper analysis and expert consultation, and once tooled and in production, each succeeding order but multiplies the waste and postpones a proper solution.

Such inquiries, also, coming sometimes from uninformed sources, and sometimes from generally competent plants and customers, contain what are often utterly theoretical and useless specifications of tolerances, the attainment of which adds alarmingly and unnecessarily to production costs and to the vast total of actual loss entailed by lack of proper sales-engineering investigation.

In such cases, too, the considerable time and expense of preparing estimates and quotations are utterly wasted by all except the few who trouble to inform themselves of the customer's actual requirements. A typical case was recently observed when a well-known automotive company asked for figures on several hundred thousand small seamless flanges, on the blueprints of which the tolerance of diameter was specified as plus or minus 0.0005 in. Other rigid specifications of shape and dimension necessitated a total of six operations to produce the piece by safe practice within the specified limits—with a tool-maintenance cost, to observe the given limits, equal to the total other cost of the part.

A brief investigation in the customer's plant and measurement of actual samples in course of assembly showed that the difficult shapes and limits specified were wholly unnecessary; that the parts then in successful use were 0.010 in. large in diameter, tapered 0.010 in. where straight parallel surfaces were specified, and varied plus or minus 0.005 in. in diameter. As a result it was possible to quote on one combination operation as against the original six, with a difference of 70 per cent between the two quotations.

When such cases exist and are typical, it requires no argument to prove that the industry and its customers are suffering sorely from a lack of coördinated engineering methods.

POSSIBILITIES AND LIMITATIONS OF PRESS PRODUCTION

Neither the practical possibilities of press production nor more particularly the various and specific limitations of these possibilities are sufficiently well recognized, with the result that there is sometimes a tendency to recommend press production in cases where, for various reasons, it is neither advisable nor applicable; and furthermore, in cases where it is properly adopted, the full possibilities of production or function are often sacrificed or costs are uselessly increased by unnecessary or merely theoretical specifications due to incomplete knowledge of actual production conditions and their present practical limitations.

The day is not far distant, in fact it is already here, when every alert manufacturer will call as freely and promptly upon his pressed-metal engineer to consult on problems of design and production, as for years he has called upon other branches of the engineering profession for technical and expert advice and assistance on problems too highly specialized for him to solve safely alone; and conversely, the day is also here when fewer and fewer companies dare or desire to quote blindly to a blueprint calling for limits of variation of 0.0005 in. (which, by the way, are increasingly frequent since the war), nor on designs of whose function or specifications of use they have little or no knowledge.

FIRST COST VS. ULTIMATE ECONOMY

Many companies today minimize any emphasis on the engineering skill and experience required to handle successfully a large volume of redevelopment work, although such skill is indisputably required and expected. As a result it is perfectly natural, therefore, that the usual customer, not stopping to analyze the situation and not having been told the facts of the case, regards the transaction of purchasing pressed-metal parts purely as a matter of competitive selection primarily on a basis of price or first cost. If he knew the real facts, however, and sooner or later he must and will be brought to see them, he would recognize that wholly apart from first cost there is a world of difference in the actual engineering service that he may receive from one concern or another, depending on its policy and experience, and that properly his selection should be guided by a consideration of that fact and by the scrutiny of ultimate cost and economy.

THE QUESTION OF TOOLS

Certain trade practices and customs that have gradually imposed themselves on the heterogeneous and formless growth of the industry have proved unpopular and prejudicial to easy expansion, such as the old question of ownership and removability of tools. Such questions present ample opportunity for careful study and investigation in themselves, and their solution is thereafter largely a matter of gradual education of the trade. As to tools, for instance, it is easily demonstrable to any fair-minded customer that in paying a preliminary "tool charge" or "tool expense" or "cost of tools" he is not thereby purchasing a physical asset, removable or transferable to his order, but is in effect purchasing primarily a service covering not alone the physical construction of the tools, but also the necessary and expensive preliminary engineering work involved in redesign and redevelopment and the actual designing of the tools; and that his payment of such a service charge is but his proper contribution for the services and toward the maintenance of an organization competent to perform the specialized character of work he requires.

Another hindrance to extensive redevelopment work is the difficulty that sometimes arises of protecting exceptionally successful redevelopments, many of which present nothing patentable either in process or result, but which nevertheless represent distinct and often valuable improvements over current practice. This, too, is remediable to a certain degree—primarily by the rendering of such exceptional all-around service that no other source of supply will be required or considered by the customer—and even this condition can often be strengthened by voluntary agreement between the company and its customer in consideration of the particular service admittedly rendered and received.

It would seem a logical and demonstrable conclusion that the greatest rewards of the next decade will accrue to those companies that develop with the greatest intensity this waiting field of redevelopment.

DEVELOPMENT OF ENGINEERING STANDARDS

Another field, already mentioned, in which little available work has as yet been done and one that cannot much longer be disregarded as the industry develops, is the determination and establishing of engineering standards for the industry—such as the standardization of data for various types of redevelopment work—as well as the usual standardization of operations, processes, and costs.

Some brilliant and exceedingly valuable work has been done in this field by and for individual companies, but much more might be accomplished coöperatively for the general benefit of all.

Some concerns, especially those controlling their supplies of raw materials, have made progress in the scientific investigation of qualities of materials most suitable for specific operations and results, but an immense saving to the industry at large might be accomplished by proper coöperative and collaborative experimental work for the benefit of each, between a pressed-metal and a raw-material group.

Generally speaking, most of the inquiries resulting in new business are now received from prospects or customers *of their own volition*, with a request for quotation and often for suggestion or information. This would indicate that there is a general and unsatisfied quest for possible improvements in the minds of many potential customers in various industries—as if there were a vague premonition of benefits to be obtained from this vigorous and fertile young industry, whose resources seem so varied and inexhaustible.

The Pressed-Metal Sales Engineer

It is in the positive fulfilment of this vague and widespread premonition that the industry is about to render its greatest service to industry at large, making broadly available its already immense store of useful knowledge, its facilities, and highly specialized skill accumulated to date. To accomplish this it must do its work through a hitherto almost unrecognized agent, the pressed-metal engineer, before whom lies an opportunity almost incredible in its richness and extent. Of this coming type of pressed-metal sales engineer and of his specific work only a few general suggestions may be given here, interesting as the field it opens may appear.

Having been accorded an opportunity to survey and study the products of the prospect, a peculiar combination of qualities in the sales engineer is called into play; primarily, he must be able to visualize and apply to each sample and problem submitted all of the present and possible facilities of his plant, and also to suggest competent sources for such work as lies beyond his capacities or equipment, thus making or helping a friend at both ends of the transaction; more particularly, he must be able to sense and evaluate all the alternate possibilities of each part presented to him—to determine whether further study on the part is advantageous and desirable.

He must elicit and consider not only all specifications requested, but all actual specifications of use—resistance to shock, strain or wear, finish, appearance, the elimination of difficult or impractical demands, and the tentative acceptance of possible and practical substitutes. Thus he must provide all the preliminary information necessary for a continued study of the conditions that will lead to the design of a part that can be produced by known and practical operations, retaining all advantages of the original and securing as many additional advantages of design or function as may be. In work of this character the greatest success is naturally achieved by one of strong imagination, of creative and inventive ability combined with the widest possible knowledge of practical operations.

Use of Sketches and Models in Sales Work

Rough free-hand sketches are very useful to convey clearly to the mind of the customer the alternative methods and designs and to serve as a basis of discussion of the relative advantages and limitations of each suggestion. Once the final design is determined upon, a simple distinct drawing or isometric sketch of the proposed redevelopment is of the greatest assistance, and if it is attractively executed and properly utilized in the actual "selling" it is often sufficient to turn the scales and close the contract.

The strongest appeal, of course, and one that seldom fails to convince the prospect, is the actual hand model, by which theoretical advantages become not only visible but tangible and existent. In many cases, however, the making of a hand model is wholly impractical or even impossible, especially in the field of large heavy work. But even in light work, where it is often possible, it must be used only with discretion, or what should be a productive tool becomes an expensive model shop.

Examples of Pressed-Metal Design

In selecting examples for illustration the intention has been to approach the problem primarily from the point of view of the sales engineer rather than from that of the technician or production expert—to attempt to show by a few selections how redevelopments have been made in typical cases rather than to study the particular tools or operations by which they have been produced; and to show to what extent in the cases involved it has been found possible to apply the processes of press production, and with what results.

The examples have been chosen to illustrate redesigns or redevelopments into pressed metal of (1) single parts, (2) simple assemblies, and (3) complete redevelopment of assembled devices or machines.

The redesign of single pieces includes several distinct fields, of each of which separate illustration is afforded: redesigning into pressed metal of parts originally designed as iron, brass, aluminum, and malleable castings, screw-machine products, die castings, forgings, etc., with distinct problems and resulting advantages peculiar to each.

It should again be emphasized that every case of possible redevelopment must be considered as a problem by itself, regardless of its field or group and regardless of certain general statements that usually apply as to the unique problems of that particular field, and to apply any such even guardedly general statements to any one case without a review of all its specific and peculiar facts, would be to miss entirely some of the most promising opportunities for brilliant work.

In all fields, of course, redesign is only practicable when either the resulting economies of production or other advantages inherent in the pressed-metal design are sufficient to offset the initial cost of tools and development.

Acknowledgments

The author is indebted to the Western Electric Co., Hawthorne Works, Chicago, Ill., the Deep Drawn Metal Corporation, Brooklyn, N. Y., and the Stewart-Warner Speedometer Corporation, Chicago, for the photographs reproduced in Figs. 3, 9 and 10, respectively.

Discussion

C. GABRIEL,[1] who was the first to discuss Mr. Cook's paper, commented on it from the viewpoint of the press manufacturer. Customers would present their problems and ask for a press tooled to make a certain part, and it was difficult to convince them of the amount of time and experimental work required to develop dies that would stand up under operating conditions. They would also ask for automatic machines, but would fail to recognize that in a sequence of operations there might be one or two that would give trouble and lay up the machine for repairs. The best way was to do as much as possible on one machine and to put the operations giving trouble on a separate press. In any case the design of an article should be studied by an experienced engineer with the view of modifying it so that it would lend itself to proper methods of tooling and to the use of dies that would stand up under the work.

R. I. Miner,[2] told of the growth in the industry, which he attributed largely to the automobile. The company with which he was connected made over two hundred different stamped-metal parts for the automobile alone. The brake drum always came in for a great deal of consideration. One to which he called special attention was for use on motor trucks and consisted originally of a half-inch plate, 39 in. in diameter which was cold drawn into a flanged shell 25 in. in diameter and held within 0.020 in. of roundness. These parts were produced at a rate varying from 75 to 100 per hour.

Murray Springer,[3] stressed the importance of developing the service value of pressed metal. His concern had been interested in finding new uses for pressed metal and an investigation which they had instituted had resulted in their receiving over 2000 suggestions of novel ways of employing it.

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[1] Consulting and Designing Engineer, E. W. Bliss Co., Brooklyn, N. Y. Mem. A.S.M.E.

[2] Assistant Chief Engineer, The Bossert Corp., Utica, N. Y. Assoc-Mem. A.S.M.E.

[3] Pressed Metal Trade Extension Council, Chicago, Ill.

Stress Distribution in Rotating Gear Pinions as Determined by the Photoelastic Method

By PAUL HEYMANS,[1] CAMBRIDGE, MASS., and A. L. KIMBALL, JR.,[2] SCHENECTADY, N. Y.

This paper gives some further results of the scientific study undertaken by the General Electric Company for the development of superior electric-railway motor pinions. It is a continuation of work started and reported upon before the Society last year. The work described was performed at the Massachusetts Institute of Technology. Its object was to find out the effect of rotation of a pinion on maximum stress for different speeds of rotation. The results given are from preliminary observations.

IN A PREVIOUS PAPER entitled Stress Distribution in Electric-Railway Motor Pinions as Determined by the Photoelastic Method,[3] the authors presented the results of their investigation of the stress distribution in certain types of electric-railway motor pinions when a static couple was applied.

The desirability of studying the stresses in rotating pinions at various speeds by the same method has been recognized by the authors since the beginning of their work, and was furthermore mentioned during the discussion of the above-named paper. A method which has been developed to accomplish such an investigation is described in the following paragraphs and some preliminary results obtained by its use are given.

A later paper will give particulars regarding a more thorough investigation, now in progress, of the stresses in gear teeth at different speeds of rotation.

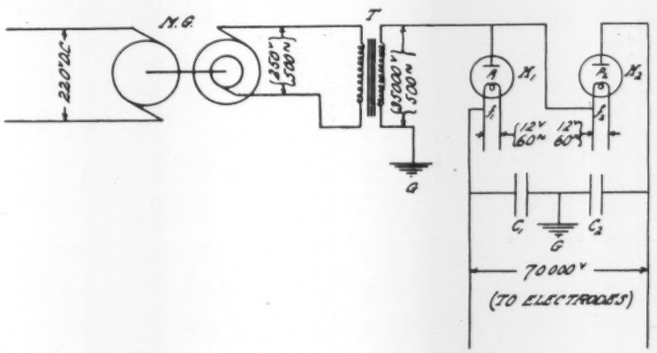

FIG. 1 HIGH-VOLTAGE KENOTRON RECTIFIER

(*M.G.*, motor-generator; *T*, transformer, H_1, H_2, kenotron tubes; f_1, f_2, filaments of tubes; p_1, p_2, plates of tubes; C_1, C_2, glass-plate sheet-iron condensers; *G*, ground.)

The authors acknowledge with thanks the valuable coöperation of Messrs. W. Dietz and T. H. Frost.

Description of the Apparatus Employed

In order to measure by means of the photoelastic apparatus the stress at a given point of a rotating pinion that is shrunk on to a shaft and is transmitting torque, it is necessary to obtain a stationary image of a tooth while it is in motion. Since the colored image is continually changing as the tooth passes through the field of view, there is but one instant during each revolution of the pinion when the stress distribution in a particular tooth repeats itself. Therefore, by using an electric spark to furnish illumination at just this instant during each revolution, and by projecting the repeated image on a screen or on a colored photographic plate a permanent stationary image can be obtained which can be analyzed and photographed provided the sparks recur a large enough number of times.

A static induction machine was first used to obtain sparks, but was found to be too much subject to oscillatory effects, due mainly to temperature, moisture, and the ionized condition of the surrounding atmosphere. A kenotron rectifier—a high-voltage condenser set, described later—solved the problem, evenly recurring sparks being obtained up to a frequency of 20 per second.

The electric-spark spectrum, however, differs considerably from the spectrum of the mazda lamp previously used, in that it has a predominance of blue-violet and ultra-violet radiation. The use of the spark in this photoelastic investigation was necessarily preceded by the analysis of the spark spectrum with electrodes of different kinds. The proper light filters and the sensitizing solutions for the autochrome lumière plates, used in the recording of the stress distribution in the photoelastic analyses, had also to be developed.

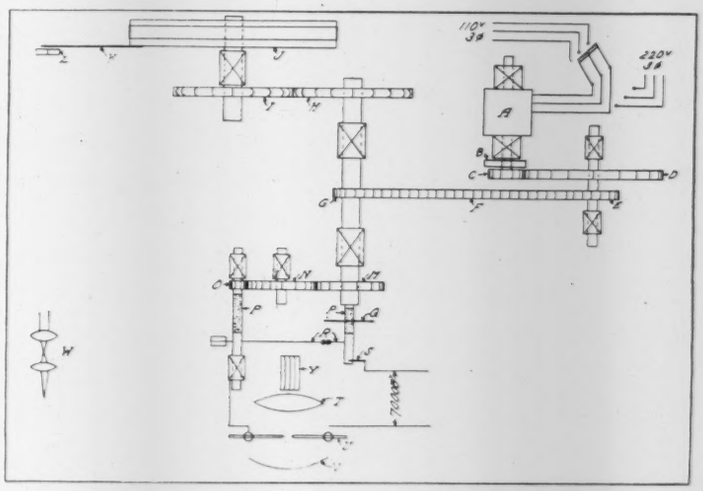

FIG. 2 DIAGRAMMATIC PLAN OF DRIVING ARRANGEMENT FOR THE GEAR MODELS

(*A*, 2-hp. 3-phase induction motor; *B*, band brake; *C*, *D*, spur gears; *E*, sprocket; *F*, chain; *G*, sprocket; *H*, celluloid gear pinion; *I*, celluloid gear pinion with expansion ring; *J*, band brake with dynamometer; *K*, sighting arm; *L*, fixed index; *M*, *N*, *O*, spur gears; *P*, fiber shaft; *Q*, fiber shield; *R*, arms; *S*, brush; *T*, collecting lens; *U*, electrodes; *V*, reflector; *W*, telescope; *Y*, polarizer and analyzer.)

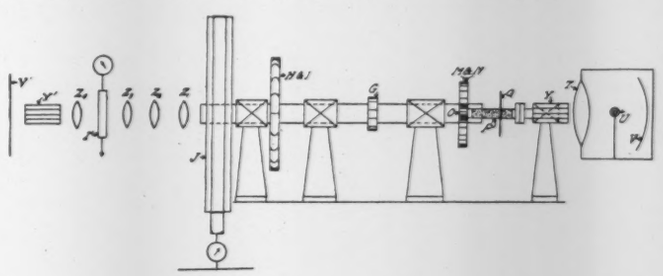

FIG. 3 DIAGRAMMATIC ELEVATION OF ARRANGEMENT SHOWN IN FIG. 2, WITH PHOTOELASTIC APPARATUS INCLUDED

(*I'*, comparison member for stress determination; *V'*, screen or photographic plate; Z_1, Z_2, Z_3, Z_4, lenses. Other letters as in Fig. 2.)

The first tests, carried out with a 40,000 to 70,000-volt spark obtained by aid of a 40-in. glass-disk static induction machine, were tedious on account of the irregularities of the light source, and required a four-hour exposure at the rate of two sparks per second. The replacing of the induction machine by a two-kenotron tube-condenser set made possible a very accurate timing of the spark in synchronism with the rotating pinions; the replacing of the light filters interposed in the path of the light before reaching the photographic plate by proper sensitization of the plates themselves for the less intense parts of the spectrum of the spark, brought the exposure down to 500 sparks, that is, to about four minutes at the rate of two sparks per second.

[1] Asst. Prof. at the Massachusetts Institute of Technology. Assoc. Mem. A.S.M.E.

[2] General Electric Co., Research Laboratory.

[3] Trans. A.S.M.E., vol. 44, p. 513.

Presented at the Annual Meeting, New York, December 3 to 6, 1923, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

Fig. 1 is a diagrammatic representation of the kenotron-condenser apparatus and the connections employed. Fig. 2 is a diagrammatic plan view of the driving arrangement for the gear models and the means of applying known and constant loads to the models when rotating.

Referring to Fig. 2, the speeds of rotation of the gears H and I which were being tested were controlled by the spur gears C and D.

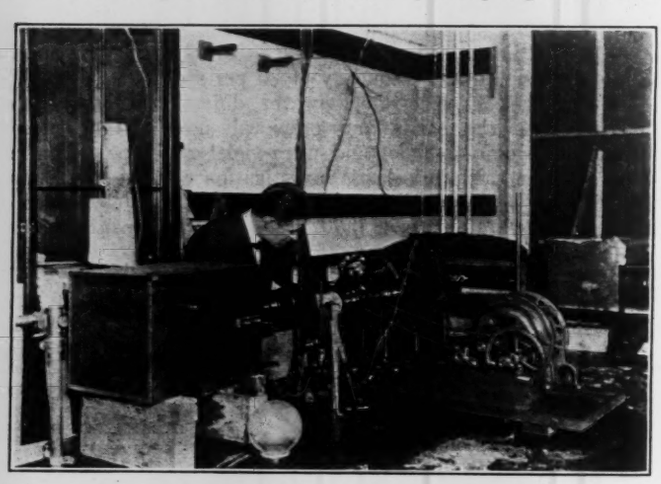

FIG. 4 VIEW OF SET-UP EMPLOYED IN THE TESTS

A chain drive F was used to connect the sprockets E and G, as it gives a positive drive but not too rigid a coupling. The celluloid gear H drove the celluloid gear I which was mounted on an expansion ring that allowed the application of radial shrinking pressure. On the same shaft with I was a band brake J and dynamometer by means of which a known resisting torque could be applied to the gears.

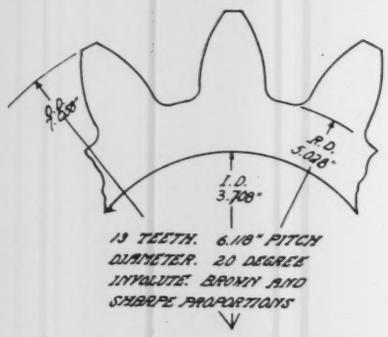

FIG. 5 TOOTH FORM OF PINION SUBJECTED TO PHOTOELASTIC ANALYSIS

The reproduction of conditions of contacts was secured by the aid of a sighting telescope W which made it possible to line up the sighting arm K with the fixed index L, resulting in the synchronous working of the spark and contact of the gears at chosen points.

The revolving arms R controlled the spark, their gap being in series with the electrodes. The frequency of the spark varied with the speed of the pinions.

Fig. 3 is a diagrammatic elevation of the arrangement shown in Fig. 2, with the photoelastic apparatus included. Fig. 4 is a view of the set-up employed in the tests.

THE TESTS

Two celluloid sections of $^1/_4$-in. face and of the type of pinion shown in Fig. 5 have been examined thus far. The radial pressure applied corresponded to a maximum $(\widehat{rr} - \widehat{\theta\theta})$ at the bore of the pinion of 845 lb. per sq. in. where $\widehat{rr}$ and $\widehat{\theta\theta}$ are respectively the radial and tangential principal stresses.

A resisting torque of 125 in-lb. was applied, giving a total tractive force per inch of face of the pinion, tangential in direction to the pitch circle, of 164 lb.

As long as Hooke's law of linear proportionality between stress and strain holds, any linear simultaneous proportional increase of the radial pressure and the tractive force will produce the same linear proportional increase of the stresses set up in the pinion. Therefore the loads applied to the model will correspond to different loads in the steel pinions bearing the same ratio as in the model. In other words, the celluloid model will give a true reproduction of the stress distribution for a steel pinion under corresponding loading conditions. To transform from the model to the steel pinion, multiply the stresses in the celluloid pinion by the ratio of the loads on the steel pinion to the loads on the celluloid model.

The maximum tensile stresses occurring at the root of the tooth in mesh have been measured for different speeds. The results for the model and for the steel pinion are given in Table 1 and the maximum stresses are plotted against increasing speed in Fig. 6.

TABLE 1 RESULTS OF TESTS OF CELLULOID MODEL AND STEEL PINION

R.p.m.	Maximum Tension[1] (lb. per sq. in.) Celluloid model	Actual pinion[2]	Per cent increase compared with static torque
0	1220	36,400	0
360	1410	42,000	16
720	1610	48,000	33
1170	1960	58,400	62
1248	2320	69,200	92

[1] At the root of the tooth at the tension side.
[2] For a ratio of torque and inside radial pressure in model and steel pinion of 1:297.

What is particularly noticeable in the results presented in Table 1 is the marked increase in maximum stress due to rotation, amounting to nearly a 100 per cent increase for a speed of 1250 r.p.m. These results are extremely interesting, though of a preliminary nature. The study is being continued.

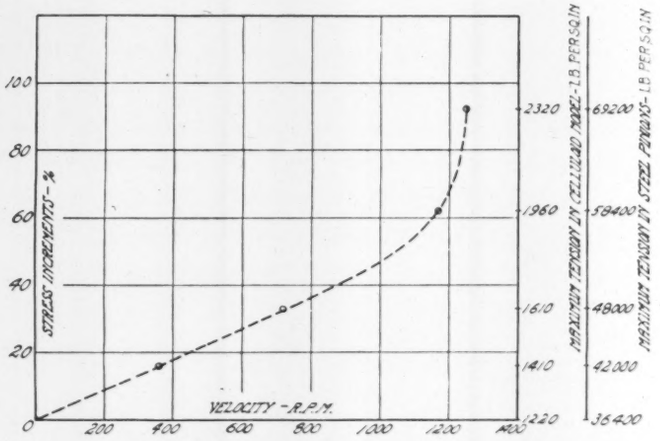

FIG. 6 INCREASE OF MAXIMUM TENSION IN CELLULOID MODEL AND STEEL PINION WITH INCREASING SPEED

Discussion

IN THE first of the written discussions to be read, S. Timoshenko[1] stated that as to practical conclusions to be drawn from the experiments made, some difficulties must be expected. It was known that due to dynamical causes the pressure between the teeth of rotating pinions might become much higher than that calculated from statical considerations. This increase of pressure could be attributed (1) to the motion of the geared system considered as a whole and (2) to irregularities in the teeth.

A geared system consisted usually of several rotating masses with elastic connections between them, and possessed some natural types of vibration which had determined periods. Subjected to the action of a periodical force it would perform vibrations, the amplitude of which increased when the period of the external force approached the period of one of the natural types of vibrations. In the case of "resonance" large fluctuations in the pressure between the teeth of pinions might be expected. Troubles of this kind happened often in geared drives for ships.

The increase of pressure produced by an irregularity in a tooth was of local character. It could be expected that this increase would be proportional to the square of velocity, which appeared to be supported by the curve obtained by the authors, and to the moment of inertia of the pinion.

In either case the pressure between the teeth of pinions while they were in motion was variable. The period of variation would be equal to the period of vibration of the geared system in the first case and very short in the second.

[1] Westinghouse Research Laboratory, East Pittsburgh, Pa.

Furthermore, the authors had used the photoelastic method to determine the pressure in but one position of the system. Although success should be obtained in mapping out the complete pressure fluctuation, the difficulty in its application to the real problem would still have to be overcome. The pressure fluctuation depended on the dynamical properties of the system and these properties would have to be produced in the model before a true analysis could be made, and, from the preceding remarks, this appeared to be impossible.

Photoelasticity was a comparatively new tool for assisting in the analysis of stress distributions, but it should be applied with caution. While the work of the authors on this problem was highly commendable, still it could not be said that a nearer approach to the actual solution had been made by making it one of dynamics. In other words, Mr. Timoshenko believed that many dynamic problems could be solved by analysis of models under static conditions with imposed forces equal to those imposed dynamically, and the authors' paper did not in the least shake his faith in this fundamental conception.

E. O. Waters[1] wrote that the paper dealt with the technique of carrying out a certain investigation rather than with the results of the investigation itself. While this was highly interesting, there was nothing essentially new regarding the principle of the method employed; whereas the results that could have been obtained if only the experiments had been carried out in a thoroughgoing manner on a variety of tooth sizes and shapes, in all stages of wear, would have provided a most valuable check on our present half-empirical mode of determining tooth stresses in gears.

Qualitatively, the curve in Fig. 6 corresponded with empirical rules which had been in use since 1893. In the Lewis formula it was assumed, without definite experimental basis, that as the pitch-line velocity of a pair of gears increased, the safe working load should be decreased; or conversely, if the working load remained constant during an increase of speed, the stress at the danger section of the tooth was increased—due presumably to impact. It was interesting to note that facts which had been assumed to be true as much as thirty years ago, had, in some measure at least, been recently substantiated by experiment.

Quantitatively, it was dangerous to draw any conclusions from the present paper, because, as the authors themselves admitted, their results were only of a preliminary nature. However, considering the rim of the experimental pinion of Fig. 5 as a thick ring under internal pressure, and neglecting the disturbance of stress distribution caused by the teeth, the standard formulas gave a radial stress of zero and a tangential stress of 460 lb. per sq. in. tension at the root of the teeth when no resisting torque was applied. When a resisting torque of 125 in-lb. was applied at zero speed, the maximum stress at the root of one tooth due to the torque alone was 1317 lb. per sq. in. according to the Lewis formula. The total tensile stress would then be 1317 + 460 or 1777 lb. per sq. in.—considerably in excess of the value 1220 lb. per sq. in. obtained by the authors for these conditions.

This result was exactly in line with the findings of Messrs. Marx and Cutter,[2] which indicated that the Lewis formula erred very generously on the side of safety. This might be ascribed to the possibility of there being more than one pair of teeth in contact on the line of action; or, what seemed more likely to be the controlling cause, to the fact that pressure between mating teeth actually was confined to the middle of the line of action. In other words, a gear tooth was not loaded at the outer end, but near the middle, and was in reality a much shorter cantilever beam than the standard formulas gave it credit for.

It was to be hoped that the authors would increase the scope of their study to include teeth of several shapes and sizes, and gear wheels in which the hoop stress caused by the shaft fit might be eliminated. Two points, at least, should be cleared up which were somewhat obscure in the present paper. First, why did the curve of Fig. 6 take a sudden upward turn above 1000 r.p.m.? If celluloid behaved like steel, a point should be reached, beyond the elastic limit, at which increased speeds would not cause any increase whatever in the stress (neglecting centrifugal effect). The corresponding flattening of the curve would not harmonize with the upturn of Fig. 6. Second, what was the position of the mating gears whose stresses were "photographed?" Were they all at the beginning or end of the line of action, or near the middle; or were results averaged for several positions? If the latter, what was the effect of position on stress?

R. Eksergian[1] wrote that in general, under static loads for ordinary engineering structural elements stressed within the elastic limit, the photoelastic method was one that distinctly led to a better understanding of the actual stress distribution. It failed, however, in the consideration of dynamic loadings, the inertia loading of the elements themselves, and in the distribution of stresses set up by temperature and shrinkage, since the conversion factors and corrections would ordinarily be so complicated that they would vitiate the very simplicity of the process.

The paper dealt with both dynamic and inertia loadings. The stresses in the hubs of the pinions were modified by the centrifugal force of rotation, whereas the dynamic loadings at the teeth were a complicated function of the inertias of the armature, wheels, etc., and the elasticity of the system between these inertial elements. The oscillations set up were due to the relative angular velocity caused by the slight irregularities in the tooth contour and in a small superimposed periodic disturbance of the driving torque. The authors had found that the stress rapidly increased with the speed, which was entirely to be expected. Thus in two simple inertia systems rigidly geared together the torque due to dynamic loading was

$$T = \frac{II'}{I - I'} \frac{d^2(\Delta\phi)}{dt^2}$$

where I and I' were the reduced moments of inertia of the system and $d^2(\Delta\phi)/dt^2$ the relative angular acceleration set up by the periodic disturbance due to slight irregularities of the teeth. It was well known, however, that for constancy of angular velocity ratio the common normal of contact must pass through the tangency of the pitch circles. With ordinary spur gears this was not obtained in practice, but the conditions were improved with helical gearing. Therefore the periodicity of the disturbance was nw, where n = number of teeth and w = angular velocity of the referred shaft. Therefore, $\Delta\phi = A\sin nw$, and $d^2(\Delta\phi)/dt^2 = -An^2w^2 \sin nw$ for the primary harmonic. The dynamic loading on the tooth was therefore proportinal to w^2, i.e., to the square of the speed. When the elasticity between the two systems was taken into consideration the results were modified so that the variation of loading with speed became more complicated, the stress-speed curve following the well-known resonance curve. It was important to point out that the stresses became greatly modified and might be reduced by the introduction of elasticity between the two rotational inertia systems. The statement that the loads applied in the steel pinions bore the same ratio as in the model was obviously erroneous (since the inertias and elasticity as well as the irregularities of the tooth contour in the actual gearing system were not comparable with those in the model), and furthermore the very object of these tests as a basis for the comparison of stresses in the actual case seemed entirely unwarranted. The static stress distribution previously contributed by the authors was of real value and seemed sufficient as far as stress distribution was concerned for the particular problem.

The problem of stress in teeth in gear pairing due to dynamic loadings was, Mr. Eksergian wrote, of considerable importance in high-speed gearing, and he accordingly had included in his complete discussion a general analysis which he had developed for the benefit of those interested in the design of such gearing.

G. M. Eaton[2] emphasized the discrepancies caused by tooth irregularity and told of a test of a double-reduction gear of about 175 hp., the teeth of which had been formed as accurately as possible without resorting to the elaboration of grinding. This gear emitted a harsh, rumbling sound or growl which, when first, studied, seemed to occur in exact phase with the revolution of the low-speed shaft, but was later found to occur at the rate of 39 growls for every 40 revolutions.

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[1] Asst. Prof., S.S.S. Yale University. Mem A.S.M.E.
[2] Trans. A.S.M.E., vols. 34 and 37.

[1] Engineer, The Baldwin Locomotive Works, Philadelphia, Pa. Mem. A.S.M.E.
[2] Ch. M.E., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Mem. A.S.M.E.

The stress in question did not repeat necessarily in exactly the same degree every time a given pinion tooth came into an exact phase relation, and it was found that to get the explanation for the maximum stress on the tooth it was necessary to take into consideration every frequency-producing mechanism in the entire structure, every tooth combination that could occur, and then determine the answer for that particular system operating under its own particular conditions. No general curves could be drawn for the use of the designer, and only the patient collection of a great mass of data would make it possible to learn the facts upon which designs could be based.

J. A. Shepard[1] said that his observations as a designer of machinery, led him to believe that the conventional methods in use would probably safeguard the strength of the gear, and hence the question of durability under service became one of more practical importance than any other with which he had come in contact. In his various efforts to analyze in order to predict in advance the probable durability of the gear tooth, he had finally come to concentrate his attention almost entirely upon the relation between the pressure of the two tooth surfaces to their relative convexities; and he would be glad if some one found it possible to evolve a rational formula by which the designer of gears could determine at the operating speeds, the proper linear pressure for gear teeth of a prescribed form, having a prescribed radius of curvature, etc.

Mr. Kimball, referring to a matter brought up by Mr. Timoshenko, said that in the authors' experiment the speeds had been low and the dimensions of the parts were such that low periods of vibrations were improbable, and he therefore believed that the curve which they had obtained did not represent a resonant condition, although he did not wish to be dogmatic about it. Further work would be done in that direction.

The curve which the authors had taken represented the condition where the ends of the teeth first came together and where the stress was practically a maximum. Just why the curve made an upward turn was a point about which they were not perfectly satisfied, and which would be the subject of further investigation. It did, however, seem to point toward what already had been believed to be true; i.e., that stresses increased with speed.

Replying to Mr. Shepard, he would say that he knew of no formula which had been derived that took account of the mounting stresses; the Lewis formula, as he remembered it, did not.

One reason why the authors were cautious in the interpretation of their results was that a celluloid model had a much lower modulus of elasticity than a steel pinion, so a load up to a corresponding fraction of the elastic limit of steel would not produce as great an elastic deflection as it would in the celluloid model; in other words, the accuracy with which the teeth were cut was disturbed more on celluloid models due to deflection than it was on steel pinions, and this had to be carefully considered.

Dr. Heymans said that he appreciated greatly Mr. Eksergian's discussion because it dealt with an aspect of the question about which he had thought considerably. When a celluloid model of a certain structure was made, if the stresses were determined directly on that model, the question naturally arose whether the loading of the model and the stresses therein measured under those loading conditions were the same or comparable to those of the actual structure whose stresses it was desired to learn.

This was really a question of elastic and inertia similitude between a model and the way it was loaded, and an actual structure. Even for statical loading the question of elastic similitude might become complicated. He might mention the case when the stresses in the structure of the *Shenandoah* were investigated. The complicated latticework which entered into the structure had to be replaced in the celluloid model by girders of rectangular cross-section on account of the reduction of size of the model. Transverse and shear wiring had to be reproduced accordingly; the conditions at the numerous joints had to be duplicated as nearly as possible, etc., the conditions of elastic similitude between the structure and the model being satisfied.

He could hardly agree with Mr. Eksergian's statement that a study of the celluloid model under dynamic loading could not be made to yield results which were comparable to those of its steel prototype. As a matter of fact he thought that it was a question of propagation of elastic waves throughout the structure which was the real point of the problem, and if it was possible to state exactly, or at least within certain limits, the comparison between the propagation of those elastic waves in two isotropic media of identical or of similar geometric, kinetic, and dynamic boundary conditions and of known relative densities, then he thought the solution of the problem might be much more useful.

It was the authors' intention to carry out the investigation first on one given type of pinions with radial pressure and then with combined torque and radial pressure in order to be able to separate and superimpose the action of the radial pressure and the torque so that, by applying the principle of superposition, they would learn what the contribution of the radial pressure was as well as that of the torque under a series of points of contact and on a certain number of different types of pinions. The question of elastic and inertia similitude would not be overlooked.

On the question of deformation of the models due to temperature conditions, which F. A. Haughton[1] had raised, he could say that the laboratory in which the work was carried on, being devoted entirely to photoelastic research, was kept under very constant temperature conditions. Although it had not been done for this first series of experiments, arrangements had been made to check the possible changes of the model, either due to such temperature conditions or due to the wear of the pinions themselves while they were in action.

Regarding the measurement of the stresses themselves, they were entirely independent of temperature conditions as the authors worked with a comparison member which was exactly the same under this very condition as the model.

Regarding the point raised by Mr. Eksergian on the question of loading conditions, he would say that the point of contact of the two teeth was observed directly by a special arm which made it possible to reproduce exactly at the same spot, for different speeds, the point of contact; in other words, they did not rely upon the angle of position of the two pinions but we observed directly the point of contact.

C. B. Hamilton[2] said that it seemed to him that if the point studied was taken at the corner of the pinion tooth, or at the initial point of the line of action, it would introduce a complicated condition that was not necessary, because more than one tooth was in action at that instant and for a short space of time thereafter, and with the deflection of the celluloid model there was obtained a distribution of stresses between two pairs of teeth, only one pair of which were being considered. If the point at which the measurements were to be made were taken a sufficient distance beyond the point of initial contact, far enough down the line of action so that there would surely be only one pair of teeth in contact, there would be a much simplified condition to study, one freed of some of the complications that had been mentioned.

J. L. Williamson[3] thought the point raised by Mr. Hamilton a very good one, but believed that it would be disastrous to eliminate the beginning of the arc of approach and the end of the arc of recession, because at the beginning of the arc of approach, since tooth deflection did take place, there was an increased angle of approach which gave something of an edge contact, and increased stresses would result. At the end of the arc of recession there was the effect of that relieving tendency of the tooth just coming into mesh. He thought it would be interesting to study the increased stresses at the beginning of the arc of approach, as had been outlined, then at the end of the arc of recession; and also when it was positively certain that one tooth was working alone.

In their closure the authors stated that they were much pleased to note the response which the paper had received in the way of discussion, and felt that the contributions had been of real value because of the new viewpoints presented.

First of all, a very important aspect of the problem had been emphasized by Messrs. Timoshenko and Eksergian. It was indeed true that the dynamics of the whole rotating system entered into the problem, and that there must exist various resonant frequencies

(*Continued on page 171*)

[1] V. P. and Ch. Engr., Shepard Elec. Crane & Hoist Co., Montour Falls, N. Y. Mem. A.S.M.E.

[1] Cons. M.E., General Elec. Co., Schenectady, N. Y. Mem. A.S.M.E.
[2] Mgr., Hamilton Gear & Mch. Co., Toronto, Canada. Mem. A.S.M.E.
[3] Western Mgr., J. O. Ross Engrg. Corp., Chicago, Ill. Mem. A.S.M.E.

The Commercial Possibilities of the Airplane

By ARCHIBALD BLACK[1] and DONALD R. BLACK,[2] GARDEN CITY, N. Y.

The authors give estimates of the capital required for financing air lines and of the cost of their operation. The major divisions of these costs are shown and the conclusion drawn that the oil companies will probably gain more revenue from the development of commercial aviation than either the airplane or engine manufacturers.

Curves are presented showing the very rapid drop in operating costs with increased operations and possible further increases are discussed. Drastic cuts in rates are shown to be possible upon the slightest increase in the headway of present lines.

Because of operating costs, the immediate field of the airplane is claimed to be that of carrying mail and packages rather than passengers, as the development of the latter traffic will have to wait until costs come down. Figures are given to show that a night air service could practically eliminate competing night-letter telegraph services for distances up to about 1200 miles.

Passenger fares are shown to be very high in small-scale operations, decreasing rapidly with increased headway to nearly those of the extra-fare trains. The conclusion is drawn that large-scale operations will bring the airplane into direct competition with the extra-fare train and that only lack of space for sleeping berths in airplanes can retard this competition. The suggestion is made that the railroads therefore investigate the possibilities of airplane operation.

AT A PREVIOUS MEETING of the Society, one of the authors of this paper presented another showing the effect upon operating costs of variations in the designed performance of commercial airplanes. In this previous paper[3] the figures were based upon U. S. Air Mail costs, which were sufficiently close for the purpose of the paper, namely, that of determining the most generally suitable performance characteristics for which commercial airplanes should be designed. Unfortunately, however (as mentioned at the time), there are many very serious cost items which enter into consideration in commercial operation which the Air Mail figures did not include. Thus they are not directly applicable to commercial lines. It was with the intention of presenting accurate data on cost of operation under commercial conditions that the following paper was prepared.

Sources of Data

Figures with nothing behind them lack authority. Therefore, before entering into a discussion of those given herewith, it might be well to make a few remarks upon their origin. Some four years ago the authors started a compilation of data on the commercial operation of airplanes with the object of making a really comprehensive study of the subject—something which then appeared and still appears to be very greatly needed. These investigations included studies of the actual practice of maintenance work and costs of lines actually in operation, of the operating equipment required, the landing-field system and equipment required, night flying and its equipment, possible losses through accidents, costs of business solicitation and every single item which enters into consideration in commercial operation. Each detail, no matter how slight, was considered from all angles and advantage taken of parallel experiences in other businesses. In the latter part of 1922 and the early part of the present year the very voluminous data collected were compiled in usable form.

Investment and operating costs were calculated for commercial air lines, starting with the operation of one airplane each way five days per week and increasing this headway in several steps up to 50 airplanes each way per day. All of the estimates were based upon what had already been accomplished and were prepared with the object of determining the probable maximums for both capital and operating cost *from the investor's viewpoint.*

The cost data tabulated were allocated under three general, twenty-three major, and eighty-one minor heads. Item by item every detail was taken up and several quotations on equipment, or estimates on maintenance work, obtained until all down to the smallest had been accounted for. Allowances were made for advertising, business solicitation, contingencies, and such items which were liberal almost to the point of being excessive. A very large sum was allowed in each case for the provision of working capital. In the case of the headway of one airplane per day, this allowance was made equal to the entire operating cost for one year to provide sufficient funds to continue, even if the line did not begin to cover expenses, until the end of the second year.

Equipment Included in Estimates

All of the estimates provided for night flying because this is necessary to compete with existing railroad services. Beacon lights, spaced 5 miles apart along the routes, are included in the cost and also small emergency-landing runways (as proposed in a previous publication[1]) spaced about 25 miles, or less, apart. Radio equipment, for airplanes as well as for fields, is included in all of the estimates. A motor-transport system for operation between station fields and the city offices is likewise included in each case. The type of airplane assumed was the conventional biplane or monoplane with a 600-hp. engine, capable of making a high speed of 125 to 135 miles per hour and carrying either 10 to 12 passengers or 1800 to 2100 lb. of packages according to the design. Under ordinary conditions these machines would be flown at about 100 miles per hour, with the engine throttled down. This would provide reserve power for use in case of head winds and would permit normal operation at about the economical speed of the machine.

The thoroughness with which the cost analyses were made may be visualized from the fact that the mere tabulation of the figures required 502 hours of working time as shown by the authors' records. They feel, however, amply rewarded for this expenditure for the reason that it gives them such complete data on airplane operating costs under commercial conditions as applied to North America. The original intention was to publish the whole study in the form of a technical paper, but it has been necessary to abandon this idea because of the volume of figures and text. Even in condensed form they would require space equal to an entire issue of Mechanical Engineering. Therefore only the totals are given in this paper, all of the details upon which they are based being omitted.

Total Capital Required

Fig. 1 shows the total capital required per mile of route to finance commercial air lines, together with the three general divisions of this capital. The equipment and other items included are as previously outlined and the lines estimated range from the operation of one to 50 airplanes per day, each way, five days per week, holidays excepted. In the case of small operations it is possible to rent landing fields. As the activity of a line grows, more and more use is made of the fields, until eventually it becomes necessary to have exclusive use of every landing field. In the cases estimated a gradually increasing rental, based upon actual rents, was allowed until the headway reached 25 airplanes per day. In this case and thereafter the fields will be used to such an extent that it will be necessary to either purchase them outright or to arrange for their exclusive use. It has been assumed that they will be purchased outright and this sudden increase in the investment explains the sudden rise in the curve. The total capital curve shows that $1690 per mile is required to finance the operation of one airplane each way per day, five days per week. In view of the care with which the estimates were prepared, the figures of any one who proposes to start a night-flying overland air line on very much less than this should be very carefully examined. The probability will be that he has either neglected some important element in his calculations, or is sacrificing reliability to first cost.

[1] Consulting Aeronautical Engineer. Mem. A.S.M.E.

[2] Consulting Aeronautical Engineer. Assoc-Mem. A.S.M.E.

[3] Influence of Design on Cost of Operating Airplanes, Mechanical Engineering, Dec., 1922, p. 821.

Contributed by Aeronautic Division and presented at the Annual Meeting, New York, December 3 to 6, 1923, of The American Society of Mechanical Engineers. All papers subject to revision.

[1] Airway Field System and Investment, *Aviation*, Feb. 27, 1922, p. 248.

TOTAL OPERATING COST

Fig. 2 shows the operating cost per airplane-mile for different headways and includes dividends at the rate shown by the upper curve. The dividend rate was fixed by considering the element of speculation in the investment and judging the return necessary to attract capital by the returns earned in other investments. As the transportation system developed the investment would become more stable, and the dividend rate is decreased accordingly. The extremely rapid drop in operating cost with increased operations, which is so very evident, is caused by the fact that many items entering into the investment and operating cost are constant or nearly

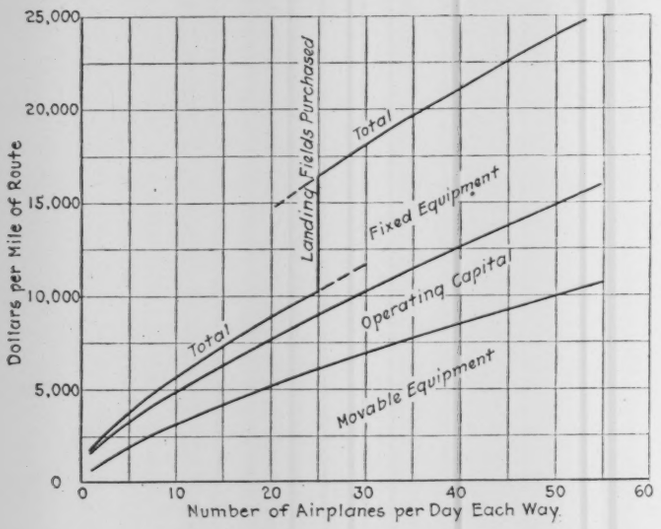

FIG. 1 VARIATION OF CAPITAL REQUIRED, PER ACTUAL MILE OF ROUTE, WITH HEADWAY
(Probable maximum costs, including night-flying equipment.)

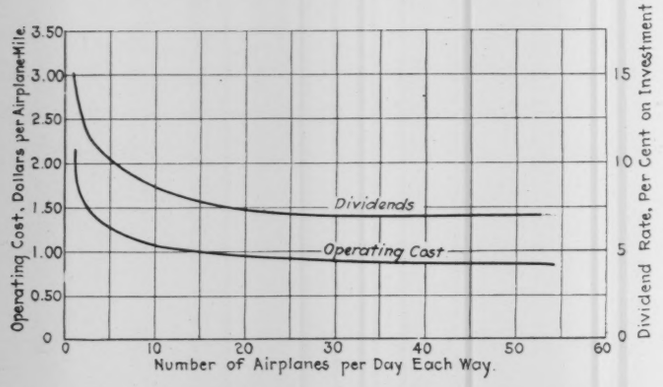

FIG. 2 VARIATION OF OPERATING COST, PER AIRPLANE-MILE, WITH HEADWAY. DIVIDENDS ON CAPITAL AT RATES SHOWN ARE INCLUDED
[94 per cent of trips scheduled assumed completed; 10 per cent allowance made for lost distance or time on trips. Night flying included. Airplanes single-engined (600 hp.) and normally flown throttled.]

constant. As all air lines today are operating on very small headway, it can be seen that very drastic reductions in their rates will be possible with the slightest increase in headway. Thus the present air-line rates are very high compared with what will be possible as soon as this method of transport becomes extensively used.

DIVISIONS OF OPERATING COST

The larger divisions of the operating cost are plotted in Fig. 3 in order to visualize their relation as the equipment becomes used more intensively. Probably one of the most noticeable features of the curves is the rapid change in the relation of the costs as the headway is increased above one airplane per day. This is particularly interesting because all of our present air lines are operating on small headways comparable with those of the extreme left-hand end of the chart. It will be noted that as these are developed the entire relation of their costs will change, making our present operating costs very misleading. The most startling feature, however, is the indication that *the development of air lines will bring more revenue to the oil companies than it will to either the airplane or engine manufacturers.* The authors have insisted, for several years past, that the aircraft industry was primarily a transportation business and only incidentally a manufacturing one. The proportion of the aircraft and engine manufacturers' revenue to that of the air line itself leaves no question on this point, if, indeed, there ever was any. Of course the objection can be raised that these gasoline and oil bills may be cut to below the authors' figures. This is probably true. No doubt they can be cut, but so can the cost of replacements of airplanes and engines by the time that fifty airplanes per day are being operated on any line.

ESTIMATES ALL LIBERAL

As previously stated, the foregoing figures are the probable maximums for both capital and operating cost. They are figures prepared *for investment purposes* and consider all possible contingencies. The minimum capital and cost figures will be appreciably below those given. The amount of this reduction is rather a matter of speculation as it will vary greatly with the routes, efficiency of the management, and the class of service maintained. If the reliability of the route is to be sacrificed, a very substantial reduction can be made in both investment and

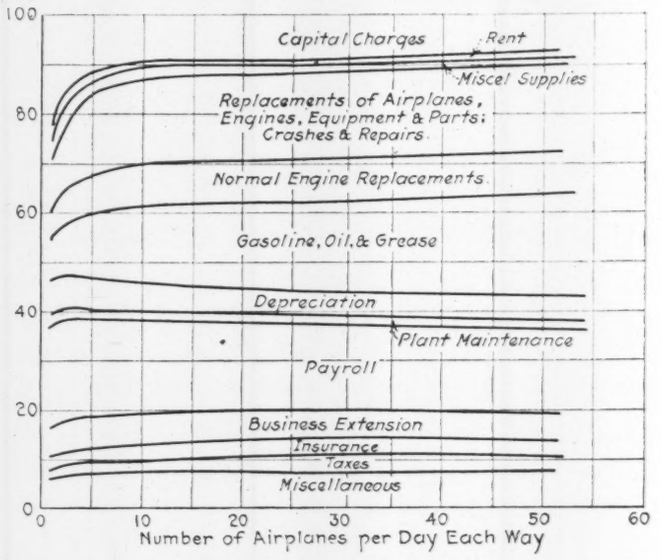

FIG. 3 DIVISIONS OF OPERATING COST AND THEIR VARIATION WITH HEADWAY

operating cost. However, the authors regard this as a practice which would probably defeat its own ends by decreasing the volume of business obtained. If the management is reasonably efficient and the percentage of scheduled trips completed on time is planned to be not less than that of the railroads, it would appear reasonable to expect the investment to be reduced by 5 to 10 per cent and the operating cost by about 10 per cent in the case of the smaller lines. When the large headways (25 to 50 airplanes per day) are considered, very many economies will be possible in addition to the few absolutely certain ones that have been already allowed in the figures.

POSSIBLE INVESTMENT REDUCTIONS

Let us consider what economies may be possible in the case of the largest lines considered. Taking, first, the matter of investment, we can foresee the following: Even if none of the airplanes are stored in the open, the hangar investment may be cut 57 per cent by the adoption of airplanes with folding wings. By raising the yearly mileage per machine, through more intensive use, from 50,000 to 100,000, the airplane, airplane equipment, and engine investment may each be cut 50 per cent. In case any one regards this as an excessive mileage, it may be stated that one of the most successful European air-line operators claims that 220,000 miles per airplane per year is possible. The motor-transport allowance made in the authors' figures provides sufficient capacity to transport the

total capacity of the airplanes at every stop. As a large proportion of the traffic will be carried more than one station, this investment could be cut perhaps 25 per cent. The working capital provided for the large lines is equal to the entire operating cost for three months. As most of the shipments will be on a cash basis and the company would do much of its purchasing on credit, this capital might be decreased 67 per cent by providing only an amount equal to one month's total operating expenses. With the allowance for the reductions in operating expenses mentioned below, this operating capital would be further decreased. The totals of the above would reduce the necessary investment by about 35.6 per cent, while other neglected or unforeseen items might easily increase this reduction. If all of the grounds were to be rented instead of being purchased, this would permit a reduction of 41.8 per cent in the new capital, but such a reduction would probably be made at the expense of increased operating costs and should not be considered.

Possible Operating-Cost Reductions

Considering now the question of operating costs, the following can be regarded as possible. The gasoline, oil, and grease allowances made in the authors' figures are very liberal and no allowance is made for increased economy or for the enormous purchases bringing any reduction in cost. On the whole, this item of cost can be cut perhaps 20 per cent through these causes. The development of the lines up to the operation of 50 airplanes per day would undoubtedly bring some reduction in the losses through accidents, although none has been allowed in the authors' estimates. Probably 20 per cent reduction would be a conservative amount to expect. The authors have carried throughout their figures the most liberal allowances for business solicitation, commissions, and advertising. By the time that the lines are developed extensively, much of the business will probably be obtained with greatly reduced effort. A 33 per cent reduction in the commissions and advertising costs may be regarded as a reasonable possibility. By the use of airplanes having quickly demountable wings, tails, etc., and having a wing covering which is more permanent than our present fabric, reductions in the maintenance costs are possible. This saving was estimated in detail and found to reach a very substantial figure. The reduction in the investment, previously outlined, carries with it a reduction in the dividend or interest charged as operating expense. The net result of all of these reductions was estimated in detail and found to reduce the operating expense by about 13½ per cent. It should be noted that no allowance has been made for an innumerable number of small economies or for radical developments in operating equipment, the only allowances made being the major ones, which can already be foreseen as possible. It is therefore quite possible that this reduction in operating costs might reach 25 per cent.

Package-Transportation Costs

The curves in Fig. 4 show the cost per pound-mile for transportation of packages at a profit and the variation of this cost with loading and headway. The rapid drop in costs as the headway is increased was, of course, indicated in Fig. 1. The authors regard the question of cost of package transportation as one of the most important at this time. As will be shown later, the cost of passenger transportation will necessitate very high rates while the lines are being operated on small headway. Consequently passenger business cannot be relied upon unless the competition is exceptionally poor. This condition will seldom be found in the United States, but may be encountered in some of the extreme northern parts of Canada, and in Alaska, at certain periods of the year. The package rate shown is admittedly high in comparison with express rates. For example, to send a 1-lb. package from New York to Chicago by express would cost 38 cents, while the airplane rate would be about 88 cents on the 2000-lb. load basis or $1.30 on the 1350-lb. basis. Which scale of rates was fixed would depend upon how nearly a full load was being carried daily. The authors regard a rate of at least $1.50 per pound as advisable at the start. This could be steadily cut until, on the largest-scale operation with nearly full load, it would be only slightly above the express rate for small packages but appreciably above it for the heavier packages.

Saving of Time in Transit

Regarding the time in transit, the authors find that the air line could accept packages at its office in New York up to 6.00 p.m. under a guarantee of delivery anywhere in the business section of Chicago *before 8.00 a.m. the following morning.* Using a fast passenger (but not extra-fare) train, the express company would be at least 24 hours—and more probably 48 hours—behind this time. The mere statement of time in hours, however, does not bring out the really important point: Measured in business days the New York–Chicago trip takes *no time at all* by air as against *one or two days* by express. The question, then, is whether or not this justifies the extra rate from the shippers' viewpoint. The authors are thoroughly convinced that it does for a certain class of packages, and this is borne out by the opinions expressed by officials of the express companies. Time is vital in the case of bank clearances, motion-picture films, newspapers, and news matt, not to mention the thousand-and-one items such as repair parts which may be urgently needed. Consider a case of a repair shop in New York. Some special part is wanted from the factory in Chicago and the factory is called on the long-distance telephone, perhaps at 5 p.m.

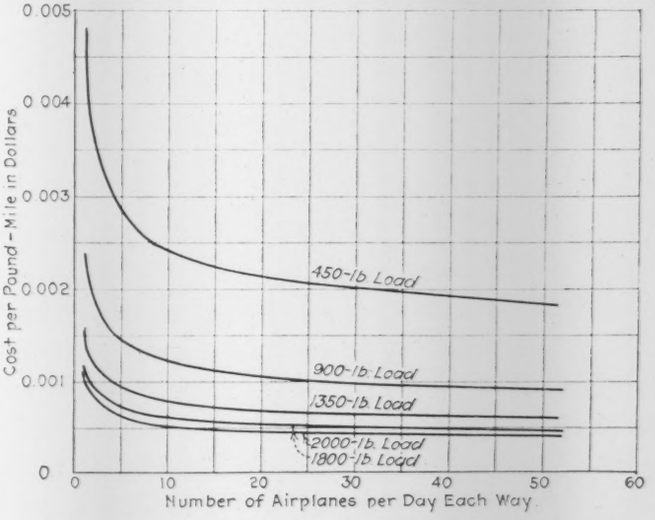

FIG. 4 VARIATION OF FREIGHT COST WITH HEADWAY AND LOADING
(Horsepower of engine, 600; total pay load, 1800–2100 lb.; maximum speed, 125–135 m.p.h.)

The part is delivered in New York next morning before the mechanics start work. Lost time, none. Lost time using express, probably two entire days. The question is, will people pay $1.50 a pound for this kind of service?

In the example cited the long-distance telephone call would cost $4.65 or over. It seems reasonable, therefore, to assume that the rate will justify itself. The authors hold that in this work and mail carrying, rather than in passenger carrying, lies the immediate field of the airplane. The passenger business will come later as soon as we get the cost down and operation stabilized. The European development of passenger lines must not be allowed to mislead us. American conditions differ in many ways, and, while we can learn many things from European air lines, we can learn some of them wrong.

Night-Letter Service

Fig. 5 shows the cost of carrying mail at a profit and the effect of varying the load and operating headway. It will be noted from the curves that, operating on the smallest scale and with only a 450-lb. load (less than 25 per cent capacity), a letter of the average weight can be carried for 0.01188 cent per mile. To this must be added the cost of messenger service for collection and delivery as well as the two-cent postage stamp necessary to comply with the postal laws. It should be safe to assume that the telegraph companies' charge of 24 cents for local messages is sufficient to cover all of these costs. On this basis, the air line can carry *signed* letters (containing perhaps 1000 words) from New York to Chicago for 34 cents using messenger delivery, or 22 cents using the Post Office special-delivery system. This compares with the telegraph com-

panies' night-letter rate of 60 cents for the first 50 words and 12 cents for each additional 10. Each message would be collected at the close of the business day and delivered before 8 or 9 o'clock the following morning. It seems unnecessary to point out that the establishment of air-line service of this type will practically wipe out the telegraph companies' night-letter business for all distances below about 1200 miles. For greater distances we could not complete in delivery time. The interests of the telegraph companies would be best served by their coöperating with air lines by handling the collection and delivery part of the air-message business. The lower rate and other advantages would greatly increase the number of messages, so it is quite possible that the net result might actually be an increase in their revenue under such an arrangement.

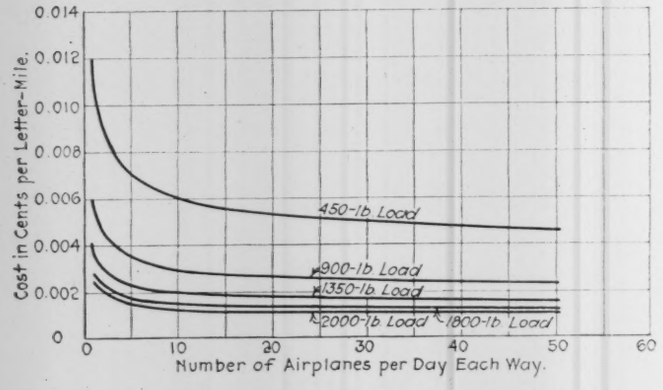

FIG. 5 VARIATION OF COST PER LETTER-MILE WITH HEADWAY AND LOADING

(Horsepower of engine, 600; total pay load, 1800–2100 lb.; maximum speed, 125–135 m.p.h. Curves based on an average of 40 letters per pound.)

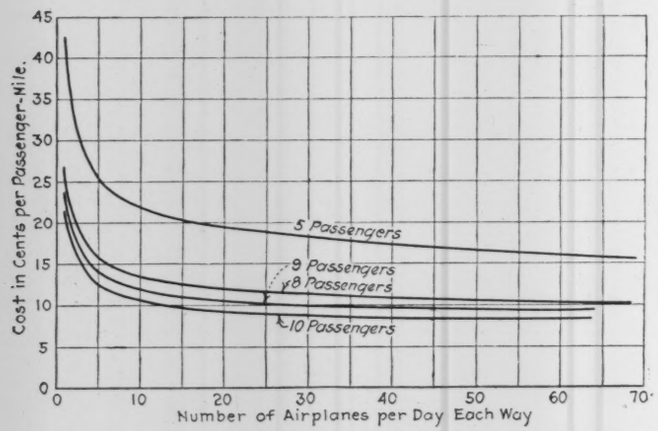

FIG. 6 VARIATION OF COST PER PASSENGER-MILE WITH HEADWAY AND LOADING

(Horsepower of engine, 600; capacity, 10–12 passengers; maximum speed, 125–135 m.p.h.)

PASSENGER TRANSPORTATION

Fig. 6 shows the possible rates for transportation of passengers, for various loads and headways. It will be observed that the necessary fare will be very high until large headways are attained. Thus it is shown definitely that the airplane cannot *usually* compete with existing means of transportation if operated on a small scale. However, the experience of present operators has shown that it is possible to attract a limited volume of "de luxe" traffic even at these high rates. On the other hand, as shown by the curves, the fare per passenger-mile drops to 8.23 cents for fully loaded ten-passenger machines when fifty airplanes per day each way are operated five days per week. In making comparisons with railroad rates it should be remembered that the airplane rate per mile is based upon a practically straight line, while the railroad rate is based largely upon the length of the track. This is always much greater than the air-line distance and is sometimes nearly double it. To make a comparison under actual conditions, it is found that the railroad fare, extra fare, and pullman rates for the New York-to-Cleveland trip, for example, total $28.58, while the airplane rate works out at about $36.54 allowing 10 per cent for lost distance, etc.

This is not an entirely encouraging comparison for the airplane, but there are several factors yet to be considered. If the figures on possible reductions, previously discussed, be applied, the airplane rate may be decreased by at least 13½ per cent. In addition, the allowance of 10 per cent for lost distance is very liberal and it is quite within reason to expect to be able to decrease it to 5 per cent for large-scale operations. Thus the airplane rate might be reduced to about $30.57 with these favorable conditions. The objection may be raised that this rate is based upon fully loading all of the airplanes. This is quite true, but their capacity can be slightly increased over that assumed (10 passengers) and, by the time that fifty airplanes are being operated per day over routes, they will be despatched about 10 to 15 minutes apart. It should be quite practicable, therefore, to adjust the despatching so that most of the planes are fully loaded and only a few seats are unoccupied in the remainder. Also, practically the entire reduction in the airplane operating costs has been due to the intensive use of the equipment as the headway was increased from one to fifty per day. No allowance has been made for important developments in the line of very economical airplanes and no allowance has been made for any economies which cannot be definitely foreseen today. These considerations should certainly be sufficient to balance the loss of revenue due to a few empty seats.

It is stated that there is very little probability of the railroads being able to substantially cut their present fares, particularly those charged on the extra-fare trains. Assuming, then, that the railroad extra fares are permanent at their present rates, *it is evident that the airplane will enter into direct competition for this class of business as soon as we can operate on sufficiently close headway to bring our costs down.* The authors' figures indicate that this headway would have to be at least fifty airplanes per day each way. It is possible that the economies which have not been allowed for may bring the number below this figure. Certainly there is very little probability of its being much greater.

Now as to when this condition may be attained: Is it to be in the dim and distant future or within the next few years? When it becomes a matter of predicting how fast air lines will develop, undoubtedly one man's guess is about as good as another's. However, from what is known of present projected lines, it appears reasonable to expect that at least one commercial line will be operating a package service with at least one airplane each way per day between New York and Chicago within the next two to five years. The rapidity of the development will be problematical and will depend upon management as much as upon any other element. No doubt the first two years will be required to place each line upon a paying basis, and gradual expansion will follow. Once expansion starts, the rates can be cut most drastically, as the curves already given show. Every cut will increase the field of possible business and will make additional cuts possible. Thus the whole process of expansion will gain momentum as it goes. It would seem that there is a reasonable probability of the headway of fifty airplanes per day being reached in 15 to 20 years after the start of operations, and it is quite possible for this headway to be reached in as little as 10 years.

This outlook should be of considerable interest to the railroad man. Here is a new means of transport, inconceivably fast and almost on the verge of utilization, which shows great possibilities. This volume of ultra-fast express matter which we are going to carry will probably never be missed by the railroads, but their extra-fare-train traffic bids fair to be very seriously menaced. There is one element, however, which will operate to assist the long-distance passenger train, and that is the question of providing sleeping berths in airplanes. Up to the present airplanes have not been constructed with sleeping berths because they have not been required. If passengers are to be carried on all-night flights, sleeping berths will be essential. How to provide enough of them in the limited space available is something that is not known today. The authors have already done some work on this problem and found[1] that the use of berths instead of seats reduces the passenger capacity to about half. Whether or not a better solution can be

[1] Safety and Comfort Chief Essentials in Passenger Airplane Design, *Automotive Industries*, June 14, 1923, p. 1284.

found they do not know, but some of the earlier problems, since solved, looked more difficult than this one does now. In any case the railroad will still be certain to have the question of airship competition to meet. Airships promise somewhat lower operating costs than airplanes, but with speeds intermediate between those of the airplane and fast passenger train.

Whether or not the railroads would consider it advisable to make efforts to retain this de luxe traffic is another question. In the firm opinion of the authors, their most logical action would be to take over the development of airplane transportation and conduct it in parallel with their other activities. No other men are so well equipped to develop air transportation as railroad men are. This is a transportation business and not a manufacturing one. It is just because of his past experience in solving transport problems that the railroad man can do so much in developing commercial aviation.

Discussion

THE Chairman, Prof. E. P. Warner,[1] in opening the discussion, said that the importance of the investigation could not be overestimated, and that the value of the paper was increased by the very conservative estimates presented. If the estimate of 25 per cent higher fare by airplane than by extra-fare train were accepted, such a low differential for higher speed should be considered highly encouraging.

H. A. Bruno[2] said that the paper was highly speculative, and dealt with conditions that might only apply within the next five years. He criticized the choice of New York to Cleveland as an illustrative route, as being a highly dangerous and economically unsuitable one, and in general thought that speculative papers of this character misled the public.

R. R. Blythe[3] emphasized the importance of aircraft insurance, and pointed out that of ten companies that started writing insurance in 1918, only one would handle this class of business now; and this company is losing money. Experience in England was of similar character. He thought aircraft transportation a difficult pioneer game, which could be only undertaken by a company willing to lose money for one or two years, and with a minimum capital of $10,000,000.

Henry M. Crane[4] agreed with the authors in thinking that the beginning of commercial air transportation would be along the lines of high-class package delivery. The extension of night flying would be required to make the service thoroughly attractive. When the valuable work of the Post Office Department had led to a solution of the problem of night flying, the Government would be in a position to assist commercial aviation in a practical manner by establishing a limited number of night-flying routes.

Wm. B. Stout[5] wrote that he thought academic discussions were valuable, but that the only way to learn how to run an airline *was to run an airline*. The country would never have commercial aviation, until commercial air vehicles were available that could make money without any subsidies or charities. Such a vehicle would surely come.

L. B. Lent,[6] in a written communication, regretted that some of the basic data and assumptions could not have found a place in the paper, and if the studies were based on experience in the United States—restricted therefore mainly to the operations of the Air Mail Service and of the Aeromarine Airways—he doubted if there were sufficient data on which to base analysis of investment and operating costs. He thought the records of the Air Mail Service to be most trustworthy. Some of the items which the authors had included in their estimates might well have been omitted. For instance, emergency-landing runways spaced twenty-five miles apart were evidently assumed as necessary to make forced landings easy. Flying experience in the Air Mail had shown that even in fair weather, when flying against a head wind, pilots would fly at an altitude of 1000 ft. or less. In bad weather they always flew low. In case a forced landing were necessary, it was obvious that an emergency-landing runway would be useless unless it happened to be within gliding distance when it became necessary to land. An emergency-landing field was treating symptoms rather than the cause of the disease. With present knowledge, multiple-unit power plants would practically eliminate forced landings from mechanical power; and one of the essentials of commercial flying was the use of such a power plant.

The authors based their capital and operating costs on "headway" or the number of airplanes per day each way, but did not state, except by inference, what the daily mileage of each airplane was expected to be. Assuming the yearly mileage was 50,000, as intimated at the end of the second page of the paper, and that the number of trips was based on "one airplane each way per day five days per week" then the number of trips per year would be 20 for one plane, which was the equivalent of a daily mileage of about 193 miles. This was less than half what it should be. The authors admitted that one of the most successful European air-line operators claimed a yearly mileage of 220,000 miles as possible. Upon a mileage of only 193 miles per day the airplane was idle altogether too much of the time in commercial work. Doubling the daily mileage would reduce the investment in airplanes, airplane equipment, and engines 50 per cent. The whole analysis should have been based on at least 100,000 miles per year per plane instead of 50,000. An analysis based on mileage rather than headway would be more accurate and applicable.

The type of airplane assumed was inferentially the wood-and-fabric machine. Our present experience with metal machines was sufficient to justify the belief that they would supersede the older type in commercial work, if they had not already done so, and that operating costs would be materially reduced thereby. It was a known fact that the maintenance costs were a very large part of total operating costs and that this item was very much reduced by the use of metal machines, or even machines made partially of metal with coverings of plywood. Commercial work in this country would not be carried on, except for possibly a very short time, with the older-type construction. It was therefore important to know what costs had been assumed for the major items.

The capital costs indicated in Fig. 1 seemed too high, and operating costs, as indicated in Fig. 2, much too high, even for maximum figures. Operating costs shown in Fig. 2 were more than twice actual operating costs in the Air Mail Service.

The airplane showed a greater time saving and so justified its use over the longer distances. Assuming a daily plane mileage of 400 it was difficult to imagine such an immediate intensive use as 25 or 50 trips daily, equivalent to one every hour or half-hour, respectively, day and night. A daily round trip between New York and San Francisco should require no more than fourteen flights of less than 400 miles each. A round trip between New York and Chicago required but four flights of less than 400 miles each.

Morris Holland[1] was sorry that no analysis had been made of the possible business to be obtained, and while he admitted that the airplane might be utilized for the transportation of certain special items such as surgical instruments, news films, etc., he did not see any great demand for such service at the moment. He thought that the kind of country flown over was a subsidiary question to that of territory in which business could be secured.

Archibald Black, in closing the discussion, pointed out that the authors' cost were based upon past work, but not necessarily in the airplane field alone, and the investigation as regarded costs went into other fields of work. He was aware of the fact that the public was not "sold" on air travel and that it would take five years to do this. That was why he proposed establishing lines carrying freight first of all. In regard to insurance, crashes and such losses were more cheaply covered by the line itself. Flying five airplanes would be proportionately much more expensive than flying fifty airplanes. Mr. Black's reason for not giving data on which his costs were based was that it would have occupied twenty to thirty times the space of the paper. His estimates for cost were based upon Air Mail maintenance costs, and upon numerous quotations for equipment from airplane, engine, etc., manufacturers. He agreed as to the possibilities of the multiple-unit power plant, but increasing horsepower might defeat itself, economically speaking.

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[1] Massachusetts Institute of Technology, Cambridge, Mass. Mem. A.S.M.E.
[2] H. A. Bruno and Associates, New York City.
[3] H. A. Bruno and Associates, New York City.
[4] General Motors Corporation, New York City. Mem. A.S.M.E
[5] Stout Metal Airplane Co., Detroit, Mich. Mem. A.S.M.E.
[6] Cleveland, Ohio. Mem. A.S.M.E.

[1] National Research Council, New York City. Mem. A.S.M.E.

Furnaces for Burning Small Sizes of Anthracite

Their Design as Indicated by Results of a Systematic Investigation of the Furnace of a Water-Tube Boiler of 10,000 Sq. Ft. Heating Surface, Fired by Two Chain-Grate Stokers

By A. R. MUMFORD,[1] NEW YORK, N. Y.

THE purpose of this paper is to show how a systematic investigation of the composition of the gases in a boiler furnace at one of the plants of the New York Steam Corporation, led to the design of a furnace which raised the overall efficiency of the boiler.

The boiler in question was a four-drum Edge Moor water-tube boiler, 29 and 30 tubes wide and 16 tubes high, containing 10,000 sq. ft. of heating surface. The gases crossed the tubes three times in their path through the boiler which was baffled by the ordinary Edge Moor type of baffles.

A section through the center line of one of the stokers is shown as a background in all figures. Beneath the grate are four separate air chambers to which air is supplied through three wind boxes from a main air duct. In this paper the grates are considered to be divided into four sections, one over each air chamber. Each wind box is equipped with slide dampers to control the air pressure under the section of the grate above the corresponding air chamber. The fourth air chamber is divided by two vertical partitions into three compartments, each controlled by a damper, so that if a hole appears in the fuel bed, the damper to the lateral compartment under the hole can be closed to prevent too great an amount of air from entering the furnace. The two Coxe chain-grate stokers under each boiler are placed side by side and operated by means of separate controls. A center wall separates the stokers and extends to within two-thirds of the distance from the front of the furnace to the bridgewall. This center wall is racked back from the bottom, near the bridgewall, to a curtain wall at the front. The curtain wall extends from the top of the front arch to the bottom of the front water leg. The front arch is a sprung arch and is 10 ft. long, extending from the ignition arch to about eight feet from the bridgewall. The bridgewall rises vertically from the floor level to the boiler tubes and is joined to the first baffle. Coal is fed to each stoker through separate chutes, and the initial thickness of the fuel bed is controlled by the ordinary coal gates.

Functions of the Stoker and Furnace

The function of the stoker is to carry coal into the furnace, remove the refuse from the furnace, and supply air to the fuel. By adjusting the pressures in the separate air chambers, air is furnished to the fuel in the required amount so that, with the ideal stoker, all of the combustible matter in the fuel is gasified and only the incombustible matter passes over the end of the stoker to the ashpit.

The function of the furnace is to raise the temperature of the green coal entering on the grate to the ignition point and to mix the gases, rich in combustible, from one section of the stoker with oxygen from another section so that the gases may be burnt completely before they enter the boiler. If a furnace does not afford means for completely burning the gases with a reasonable amount of air before they enter the boiler, its design is imperfect. The quantity of combustible gas and excess air present in the gases as they enter the boiler shows how well the furnace performs the mixing function; and the ability to maintain ignition at different ratings shows how well the furnace performs its ignition function.

Unfavorable Features Indicated by Observation of Ordinary Operation

Observation of the ordinary operation of the boiler, furnaces, and stokers in the plant on which the studies were made indicated that losses existed because of the large amount of combustible in the refuse, because of high flue-gas temperature, and because of the presence of CO in the flue gases. The loss due to combustible in the refuse was high, partly because it was necessary to carry long fires to attain the required steam output and partly because particles of solid combustible were blown from the front of the grate and carried in suspension by the gases until the end of the stoker was reached, when the particles settled out of the gases and fell to the ashpit. The high flue-gas temperature was due to the combustion of CO in the boiler. It is evident that any combustion which takes place after the gases have entered the boiler will result in a higher flue-gas temperature, because the further away from the furnace that combustion takes place, the less the boiler heating surface available for the absorption of the heat thus generated. The loss due to CO in the flue gases and that due to high flue temperatures were evidently caused by poor mixing action in the furnace. Thus, to improve the operation of the plant, it was necessary to decrease the loss due to solid combustible carried in suspension by the gases, to burn out the refuse on the grates more completely, and to mix air with the combustible gases so that they would be completely burned in the furnace.

Method of Analyzing Conditions of Actual Operation

In order to learn how the mixing action of the furnace might be improved and to outline accurately the path of the gases through the furnace, simultaneous samples of the gases in the furnace were collected at eleven points. Six of these points were on a horizontal line about six inches above the fuel bed and five on a horizontal line just below the boiler tubes. The flue gases were sampled simultaneously by means of a special sampling tube which drew gas from the whole width of the uptake. The temperature of the flue gases was measured by copper-constantan thermocouples inserted in the openings between the drums just below the uptake. In order to eliminate any error from momentary changes in the fuel bed, the gas samples were collected over a period of twenty minutes. During this interval the flue-gas temperatures and the air pressures under the stokers were noted every five minutes.

The results of some of the studies of the furnace gases are plotted on charts, Figs. 1 to 7, inclusive. The holes through which the sampling tubes were inserted into the furnace are indicated by small circles enclosing identifying numbers. The composition of the gases at each point is plotted on the vertical line immediately above each sampling hole. The pressure of air in each of the four air chambers is represented by a horizontal line drawn across each section. In some diagrams, for the purpose of ready comparison, two sets of analyses are reported on the same chart and a heavier line is used for one of the sets in order to distinguish between them. The background of each chart is an outline drawing of the furnace and stoker as it existed during the study shown.

Studies of Combustion under Normal Operating Conditions

Fig. 1 shows the composition of the furnace gases under normal operating conditions. A study of the curves in this figure shows that immediately over the fuel bed at the front half of the furnace, there is little or no oxygen present and considerable combustible gas. At the rear half of the furnace considerable oxygen is present and little or no combustible gas. In the first pass more oxygen is present near the curtain wall than near the bridgewall, and conversely no combustible gas is present near the curtain wall although a rather large amount is present near the bridgewall. A study of these and other analyses enables a statement of the progress of combustion on the grates and in the furnace to be made.

As the coal falls on to the moving grate it is brought slowly forward and exposed to radiation from the furnace brickwork, and at nearly the same time it passes over the first air chamber in which the greatest air pressure is carried. The radiation evaporates the surface moisture in the coal, and the air forced through the fuel bed by the pressure in the first air chamber carries the water vapor formed into the furnace. After the coal is dried, its temperature

[1] Fuel Engineer, New York Steam Corporation. Jun. A.S.M.E.

Presented at a meeting of the Metropolitan Section of The American Society of Mechanical Engineers, New York, January 15, 1924. Slightly abridged.

is raised to the point of ignition by further radiation. Ignition takes place first of all at the upper surface of the fuel bed and the air passing through the layer of coal unites with the ignited coal and combustion begins. The rise in temperature caused by this combustion at the surface is communicated to the lower layers of the coal by conduction, and these lower layers then ignite and burn. After the coal is completely ignited in this manner, combustion of the whole fuel bed continues until the end of the stoker where, with the ideal stoker, no combustible is left on the grates. From the point in the travel of the grate where ignition is complete to the point of dumping, the combustible content of the fuel bed decreases steadily and the proportion of incombustible matter increases correspondingly. The influence of these changes in the composition of the fuel bed on the products of combustion is exceedingly important in the design of a furnace.

The first change in the fuel bed is the evaporation and removal of the surface moisture, and since this change is not a chemical

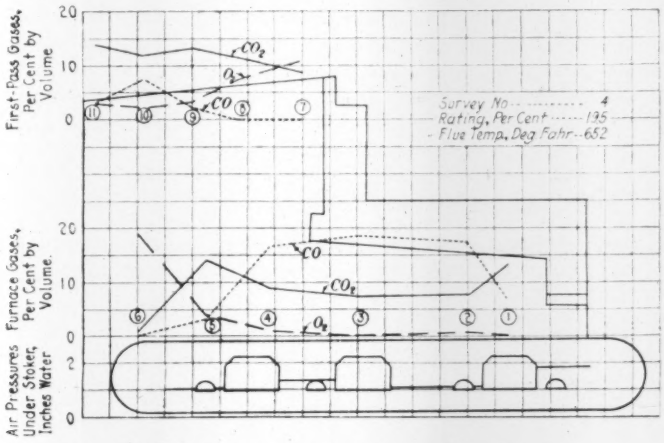

FIG. 1 NORMAL OPERATION WITH LOW ARCH

reaction it has no influence on the oxygen content of the air. The second change is the distillation of the volatile matter and the ignition and combustion of the surface layer of the fuel bed. At this point some free oxygen is present above the fuel bed and little or no combustible gas, because the layer of burning coal is so thin that the air is not in contact with incandescent carbon long enough to use up all of the oxygen.

As the fuel bed becomes fully ignited the oxygen in the air passing through the fuel is completely used up in the lower layers where it gasifies carbon, forming CO_2. As this CO_2 passes through the upper layers of incandescent fuel some of it is reduced by contact with carbon to CO. Fully one-third of the length of the grate is covered by the fuel undergoing this change, and consequently a large volume of combustible gas is formed. This action continues until the carbon or combustible content of the fuel bed is lowered sufficiently to allow CO_2 to pass through with little reduction to CO. The amount of combustible on the grate diminishes rapidly from this point on, and more and more free oxygen passes through the fuel bed until no CO_2 or CO is formed and the gases rising from the grates consist solely of air. To summarize, free oxygen is present at the very front and at the rear, while in between a large amount of combustible gas is present. In order to burn the coal completely in the furnace these three streams of gas must be mixed.

The extent of the mixing action of the furnace on the stream of gas can be seen by the changes in composition of the gases which have taken place between the grate level and the point of entrance to the boiler. At points 7 and 8, Fig. 1, no CO was ordinarily present under normal operating conditions. The burning out of CO was probably due to the fact that the air from the front of the stoker passed along just under the main arch, mixing with the combustible gas and burning it. The presence of CO at points 9, 10, and 11 indicates that insufficient air was introduced into the main stream of combustible gas.

The gaseous products of combustion evidently acquire considerable velocity as they pass under the front arch, because the gas stream could be seen to pass toward the rear of the furnace beyond the end of the main arch before turning to enter the boiler. The stream actually inpinged on the bridgewall and its direction was changed by this wall and the stack draft toward the heating surface of the boiler. The presence of the main gas stream nearer the bridgewall than the curtain wall is confirmed by the analyses of the gases entering the boiler and by pitot-tube measurements, which indicated that the velocity at points 9, 10, and 11 was four to six times that at points 7 and 8.

EFFECT OF INCREASING THE GRATE SPEED ON IGNITION

It was found that combustion at point 1 is more complete when the grate travels faster, and this indicates that more air enters the furnace at the front. An increase in air entering at the front of the furnace can only take place through green coal, and if the thickness of the fuel bed and the pressure of air in the first air chamber are the same, then there must be a larger area of green coal exposed to the pressure in the first air chamber at higher grate speeds to account for the more complete combustion at point 1. In other words, as the grate travels faster, ignition takes place later. To check these deductions, the air pressure in the first chamber was reduced while the grate was moved at maximum speed, and it was found that the gas composition at point 1 was then the same as at lower speeds. It was also found that the air from the front was responsible for the burning out of CO by the time the gases reached points 7 and 8 for, with the reduced air pressure in the first air chamber, CO was found at points 7 and 8. To circumvent the later ignition at higher grate speeds, radiation to the green coal must be increased by an increase in the area of radiating surface or by removing the obstruction caused by a thick ignition arch.

POSSIBILITIES OF IMPROVING COMBUSTION INDICATED BY A STUDY OF THE NORMAL OPERATION

A study of the normal operating conditions indicates three possibilities for improvement. If the velocity of the gases as they pass under the front arch can be reduced materially, the number of particles of solid combustible carried to the rear of the stoker will be reduced. The obvious method of decreasing the gas velocity is to increase the cross-sectional area of the furnace under the front arch by building a higher arch. If this should improve combustion at the same time, because of the resulting increase in combustion space, it will be beneficial in solving two of the difficulties.

In order to burn out the combustible on the grates more completely, more air must be forced through the fuel bed on the last stoker section, with the single qualification that it must be possible to mix the additional air with the gases so as to complete the combustion in the furnace. In other words, it must be used so as to avoid losses due to excess air.

It might be advisable to introduce air into the furnace through jets under pressure in order to complete combustion in the furnace.

All of these possibilities were tried and the results are shown in the following paragraphs.

EFFECT OF INCREASING THE AIR PRESSURE IN THE LAST AIR CHAMBER

In order to study the effect of adding more air by increasing the pressure in the last air chamber, a set of samples was collected with no change other than the increase in pressure mentioned. The results are given in Fig. 2. The light lines indicate normal operation and the heavy lines indicate the effect of the additional air introduced through the refuse at the end of the stoker.

The results show that immediately above the fuel bed the gas composition did not change appreciably at the front of the furnace, but at the rear the oxygen is much higher with the higher pressure. At the entrance to the first pass the effect of the increased air supply is very evident. The gas composition at points 7 and 8 is essentially the same for both trials. At point 9 there is evidence of a slight effect of the additional air, while at points 10 and 11 the rapid fall of the CO_2 curve and the rise of the O_2 curve show that the additional air affected the gases passing these points very materially. It is true that CO was reduced, but the reduction in CO_2 and increase in O_2 showed the method to be impractical.

EFFECT OF RAISING THE MAIN ARCH ON COMBUSTION IN THE FURNACE

In an attempt to reduce the loss from particles of solid combustible blown from the front of the grate and carried to the ashpit, the main arch was raised to the extent shown as a background in Fig. 3. The arch was raised 1 ft. at the front and 2 ft. at the rear, thus increasing the cross-sectional area at the rear by about 16 sq. ft. and by about 8 sq. ft. at the front. This is somewhat greater than a 50 per cent increase at the end nearest the bridgewall, and ought to reduce the mean horizontal velocity by the same proportion.

The composition of the gases over the fuel bed and entering the boiler are shown by the heavy lines in Fig. 3. In this figure the background shows the two heights of arches. The light lines

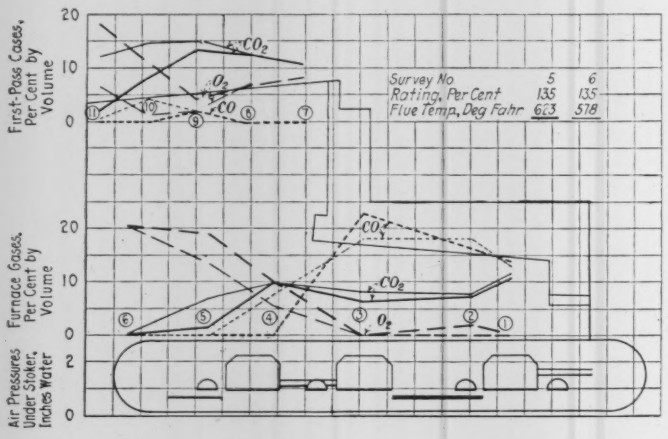
First-Pass Gases, Per Cent by Volume
Furnace Gases, Per Cent by Volume
Air Pressures Under Stoker, Inches Water
Survey No 5 6
Rating, Per Cent 135 135
Flue Temp., Deg Fahr 663 578

FIG. 2 EFFECT OF INCREASING AIR PRESSURE IN LAST AIR CHAMBER

show the composition of the gases with the low arch, while the heavy lines indicate the gas composition with the high arch.

If raising the front arch is to improve combustion, the percentage of CO_2 found in the gases entering the boiler must be higher and that of CO lower than with a low arch. It was impossible to determine exactly what weight to give the analyses at the various points, but if we assume that the points apparently in the main gas stream should be weighted according to the rough measurements of velocity that were made, points 9, 10, and 11 would have a weight of 4 to a weight of 1 for points 7 and 8, with the low arch in service. With the high arch, points 7, 8, and 9 would have a weight of 4 and points 10 and 11 a weight of 1. Using the foregoing approximation the average composition of the gases entering the boiler shown in Fig. 3 is as follows:

	CO_2	O_2	CO	N_2
With low arch, per cent	13.8	2.9	2.9	80.4
With high arch, per cent	12.1	5.4	2.8	79.7

From this it is evident that there was little change in the amount of combustible gas entering the boiler, but that there was a reduction in the amount of CO_2 and an increase of oxygen so that the gas composition was not favorable to the high arch.

It is evident that if more air were forced through the refuse it would rise directly to the boiler past points 10 and 11 without coming into contact with the main stream of gas at all. With the low arch such an increase in air supply raised the excess air, but with a high arch the effect would probably be worse in that none of the combustible gas would be eliminated by the accompanying increase in excess air.

The changes in the composition of the gases over the fuel bed were evidently not due to the change in arches.

In general, since the raising of the front arch did not reduce the horizontal velocity of the gases sufficiently to stop the loss due to particles of solid combustible dropped from the gases to the ashpit, and since the composition of the gases entering the boiler was not improved, this change was not the most desirable.

EFFECT ON COMBUSTION OF A PARTITION IN NO. 2 AIR CHAMBER

No. 2 air chamber is that space under the grates between the first and second wind boxes. The distance between the sides of these two wind boxes, in the direction of the movement of the grate, is nearly twice the distance between wind boxes 2 and 3.

A partition was installed in each of the stokers of the boiler on which the investigations were made and is indicated by the vertical line in No. 2 section on the background of Fig. 4. The composition of the furnace gases at the several points is shown by the light lines in this figure, and, at low rating, the shortness of the fire is clearly shown. Because the CO formed at the front of the fire had to pass under the front arch for a considerable distance before rising to the boiler and because oxygen was present in the gases below the arch, due to the short fire, there was somewhat less CO in the gases entering the boiler. At the same time the greater amount of oxygen passing through the fuel bed raised the excess air in the flue gases somewhat as shown by a comparison of the flue-gas composition for survey 14 (Fig. 3) and survey 18 (Fig. 4) at nearly the same rating.

EFFECT OF AN AIR JET ON COMBUSTION

The heavy lines in Fig. 4 show the effect of an air jet on combustion. The air jet was introduced through the side wall of the furnace about a foot below the end of the front arch and was supplied with air from a railway-type compressor which gave a pressure of about 25 lb. at the nozzle of the jet which was formed from a piece of $^1/_2$-in. pipe. The differences in the composition of the gases over the fuel bed were caused by slight differences in the lengths of the fire.

As shown in Fig. 4, the oxygen at points 7 to 11, inclusive, was higher with the air jet in service and the CO_2 and CO were lower.

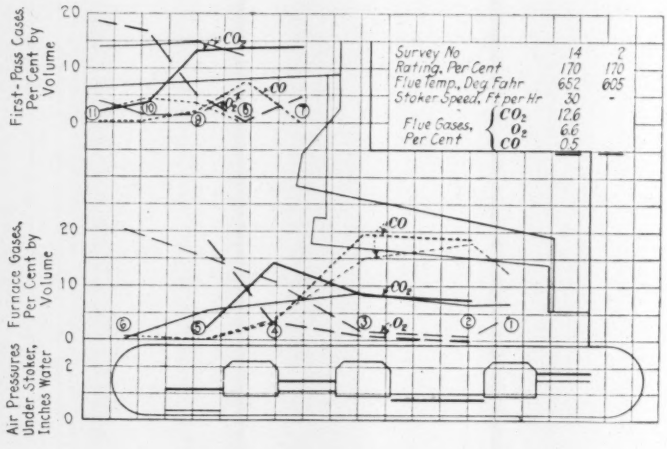
First-Pass Gases, Per Cent by Volume
Furnace Gases, Per Cent by Volume
Air Pressures Under Stoker, Inches Water
Survey No 14 2
Rating, Per Cent 170 170
Flue Temp., Deg Fahr 652 605
Stoker Speed, Ft per Hr 30 -
Flue Gases, Per Cent CO2 12.6
O2 6.6
CO 0.5

FIG. 3 EFFECT OF RAISING THE FRONT ARCH

Thus the air jet reduced the amount of CO in the gases entering the boiler, but it accomplished this with a substantial increase in excess air.

At high ratings also, a reduction in the amount of CO in the gases entering the boiler took place accompanied, as at low ratings, with a decrease in CO_2 and an increase in oxygen when the air jet was in service.

The effect of an air jet in burning out CO seems to be balanced by an increase in flue-gas loss due to excess air, so that little real benefit is derived from the use of such a jet. In addition, it is illogical to provide an air supply above the fire if air can be forced through the refuse and properly mixed with the combustible gases. That the logical place for the admission of any air necessary for combustion is through the refuse is evident from the fact that air entering the furnace in such a manner must gasify some carbon and so reduce the loss due to combustible in the refuse.

EFFECT OF STEAM JETS INTRODUCED TO SIMULATE THE ACTION OF A REAR ARCH

In order to simulate the action of a rear arch without waiting for its construction, a system of steam jets was introduced across the stoker at point 6 at the rear of the furnace. The steam jets were constructed by inserting sixteen $^1/_8$-in. pipe nipples into a 1-in. pipe 8 ft. 8 in. long, and it was assumed that they would give an indication of the probable effect of directing the air rising through

the refuse toward the front of the furnace where the necessity for such air has been shown.

The effect of the steam jets with the low arch in service is shown in Fig. 5. In this figure the light lines indicate the gas composition under normal operation and the heavy lines the composition with the steam jets in service. The combustion of the coal on the grates is, of course, unaffected by the steam jets. In the first pass, however, the effect of the additional air and the mixing action of the jets is evident. The air rising through the refuse is forced forward by the action of the steam jets and mixed with the main gas stream. The oxygen in this air is thus brought into contact with the combustible gas and combined with it, burning the CO and increasing the CO_2. The composition of the gases in the first pass shows that by the time the gases have reached the boiler tubes the CO is entirely eliminated. The following table gives a comparison of

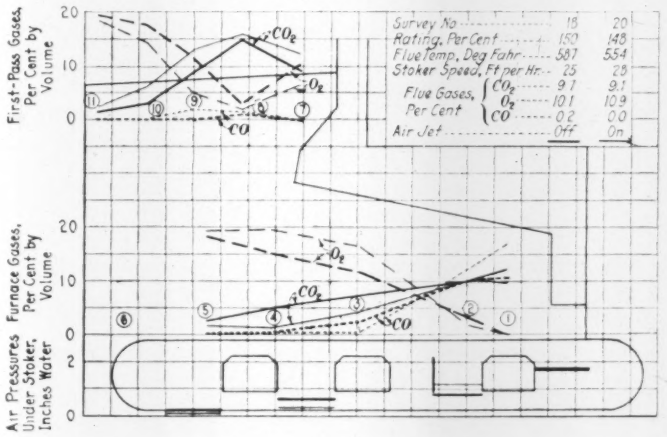
First-Pass Gases, Per Cent by Volume
Furnace Gases, Per Cent by Volume
Air Pressures Under Stoker, Inches Water
Survey No 18 20
Rating, Per Cent 150 148
Flue Temp., Deg Fahr 587 554
Stoker Speed, Ft per Hr 25 25
Flue Gases, Per Cent CO2 9.7 9.1
O2 10.1 10.9
CO 0.2 0.0
Air Jet Off On

FIG. 4 EFFECT OF AIR JET WITH PARTITION IN THE NO. 2 AIR CHAMBER

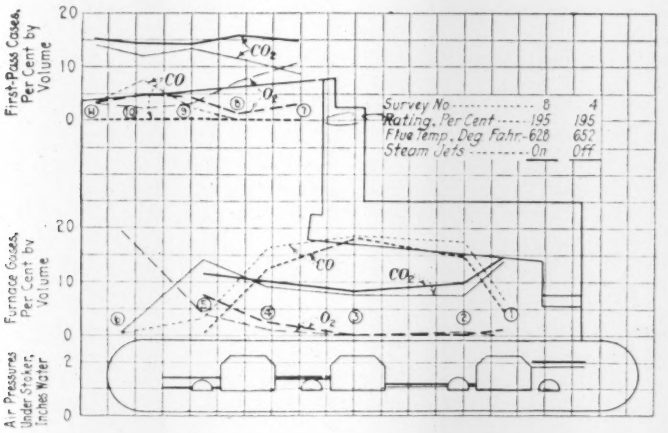
First-Pass Gases, Per Cent by Volume
Furnace Gases, Per Cent by Volume
Air Pressures Under Stoker, Inches Water
Survey No 8 4
Rating, Per Cent 195 195
Flue Temp., Deg Fahr 628 652
Steam Jets On Off

FIG. 5 EFFECT OF STEAM JETS WITH LOW FRONT ARCH

the two sets of analyses of the gases entering the boiler by means of averages weighted as formerly.

	CO_2	O_2	CO	N_2
With steam jets, per cent	14.8	4.0	0.1	81.1
Without steam jets, per cent	12.7	3.7	3.7	79.9

From these results it is evident that steam jets gave the greatest improvement of any change discussed thus far.

Because some of the arches in the boilers at the plant had been raised, it was desirable to learn the relative effect of steam jets on the combustion in a high-arch boiler. The curves in Fig. 6 show the results of an investigation on a high-arch boiler with and without steam jets. The heavy lines indicate the composition with the steam jets in service and the light lines the composition under normal operating conditions. The following tabulation gives a comparison of the weighted averages of the gas composition.

	CO_2	O_2	CO	N_2
With steam jets, per cent	12.4	6.6	0.5	80.5
Without steam jets, per cent	13.0	4.5	2.2	80.3

It is evident, therefore, that steam jets (used to simulate a rear arch) were effective with a high arch but not as effective as with a low arch. This fact is of importance in deciding the best arch arrangement over a chain-grate stoker burning small sizes of anthracite.

THE ACTUAL EFFECT OF A REAR ARCH INSTALLED IN A BOILER WITH A LOW FRONT ARCH

In order to confirm the conclusions drawn from the action of steam jets a Detrick flat-suspended arch was installed in the rear of a low-arch furnace. The rear arch was suspended 10 in. above the grate and extended 5 ft. forward from the bridgewall. The boiler was operated for several days at ratings varying between 250 and 270 per cent in order to learn the ability of the arch to withstand the heat of the furnace before a study of the furnace

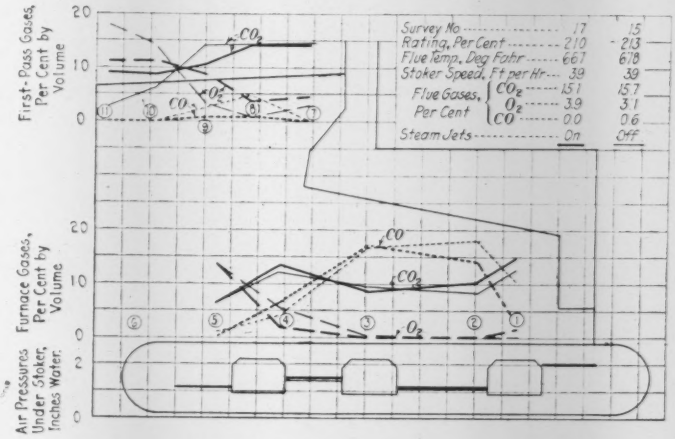
First-Pass Gases, Per Cent by Volume
Furnace Gases, Per Cent by Volume
Air Pressures Under Stoker, Inches Water
Survey No 17 15
Rating, Per Cent 210 213
Flue Temp., Deg Fahr 667 678
Stoker Speed, Ft per Hr 39 39
Flue Gases, Per Cent CO2 15.1 15.7
O2 3.9 3.1
CO 0.0 0.6
Steam Jets On Off

FIG. 6 EFFECT OF STEAM JETS WITH RAISED FRONT ARCH

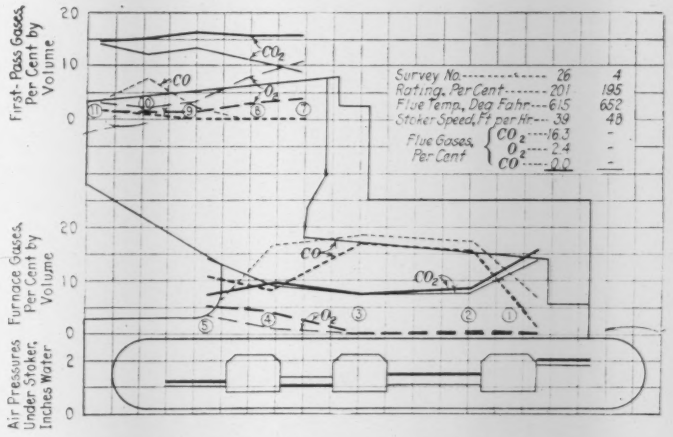
First-Pass Gases, Per Cent by Volume
Furnace Gases, Per Cent by Volume
Air Pressures Under Stoker, Inches Water
Survey No 26 4
Rating, Per Cent 201 195
Flue Temp., Deg Fahr 615 652
Stoker Speed, Ft per Hr 39 48
Flue Gases, Per Cent CO2 16.3 -
O2 2.4 -
CO 2.0 -

FIG. 7 ACTUAL EFFECT OF A REAR ARCH

gases was undertaken. During this period the dropping of particles of solid combustible matter from the gases to the ashpit stopped completely; this material dropped to the roof of the suspended arch instead and seemed to burn out, leaving a layer of ash which increased in thickness until it flowed slowly toward the grates, forming "whiskers" on the nose of the arch. The nose itself was brilliantly incandescent, although a layer of clear gas from the last stoker section seemed to cling to its surface. In rising to the boiler there seemed to be an expansion of the gas stream so that the whole width of the first pass was taken up by the gases entering the boiler.

The shape of the arch and its relation to the furnace is shown in Fig. 7. In this figure the results of a study of the furnace gases with the rear arch (heavy lines) are superimposed on those of a study of the furnace gases without the rear arch installed (light lines). Over the fuel bed the gas composition is different, although this is obviously not due wholly to the rear arch. The air pressure in No. 4 air chamber was maintained considerably higher with the rear arch in service and the refuse passing over the end of the stoker appeared well burnt out.

In the first pass the gas composition shows that the CO_2 is higher at all points and that the CO is lower. The arithmetical averages of the gas composition show that without the rear arch about one-fifth of the CO formed in the furnace entered the boiler and that with the rear arch in service only one-twentieth. These facts indicate that the rear arch as installed greatly improved the mixing action of the furnace.

The analysis of the flue gases shows a very favorable condition. The flue temperature shows a reduction of about 35 deg. fahr., which in itself is the equivalent of 1 per cent saving. The saving resulting from the favorable gas composition and apparent condition of the refuse cannot be estimated because no reliable figures are available for comparison. However, the plant records will eventually bring out the actual saving and since the saving actually obtained by the operators is the true saving, this will be the criterion on which this form of furnace design will be judged.

Design of a Furnace for Burning Small Sizes of Anthracite Fired by a Chain-Grate Stoker as Indicated by the Preceding Studies of Combustion

The first function of a chain-grate-stoker furnace is to ignite the coal. Ignition is caused by radiation from incandescent brickwork to the green coal as it enters on the grate. Ignition can be improved mainly by increasing the area of incandescent surface, and by decreasing the thickness of the ignition arch so that less coal will be in its shadow, or by both of these changes. It has already been pointed out that the nose of the rear arch became incandescent at high ratings and was hot at low ratings, and since this part of the arch looks toward the front of the furnace, radiation from it must be received by the green coal. Because the bridgewall never was heated above a dull red heat, the radiation from it to the green coal must have been less than from the nose of the rear arch, and therefore ignition was hastened by the addition of this form of arch.

The remaining function of the furnace is to mix the products of combustion so that the combustible gases from one part of the grate will be supplied with oxygen from another part and burned before they enter the boiler. The investigations reported here were carried out on a Dutch-oven type of furnace and the indications are that some such type is necessary to produce mixing. Air and combustible gases are present at the front of the stoker and some arch over this section is necessary to force the two streams into contact. Because the air entering the furnace at the front is generally insufficient to supply all of the necessary oxygen, the combustible gases from the front must be forced to pass over the refuse section of the grate in order to come in contact with the free oxygen in the gases rising from this section. This action can be accomplished by placing the stoker completely under an arch and thus preventing any of the gas from entering the boiler until it has passed over the refuse section. This form of furnace would have obvious disadvantages from the standpoint of upkeep because intense gaseous combustion would probably take place over the refuse section and the arch would be subjected to the resulting high temperature at this point. It is well, therefore, to shorten the main arch from this extreme length to a length that will permit radiation to the boiler to cool the brickwork at the point where the most intense combustion will take place. If the front arch is shortened in this manner it will be necessary to install a rear arch to prevent the gases from the refuse section from rising directly to the boiler and to force them to travel toward the front of the furnace far enough to insure their mixing with the main stream containing combustible gas. The front arch should be low enough to insure the gases having a high enough velocity so that their momentum will carry them beyond the end of the front arch and over the rear arch to the bridgewall. Combustion under the front arch can be made more incomplete than normally, if advisable, by a decrease in the air supply at the front; and the necessary oxygen for the completion of combustion can be supplied by carrying high air pressures under the refuse section of the grates.

The details of the dimensions of such a furnace would vary with the height of the setting available, because the higher the setting the more time there will be available for the completion of combustion. Conversely, the lower a setting is the more effective must be the action of the mixing devices in order that combustion be completed before the gases reach the boiler. However, it seems necessary to utilize arches in the manner suggested to give the gas streams from the front and rear of the stoker velocities in opposite directions to insure the completion of combustion in the furnace

The Binary Cycles Using Mercury and Steam

By ARTHUR M. GREENE, JR.,[1] PRINCETON, N. J.

AFTER the engineer has built an operative machine in which heat is turned into useful work or mechanical energy his aim ever has been to improve the efficiency of the machine, keeping always in mind the commercial aspect of the question, namely, the production of greatest amount of useful energy for the total expenditure of a unit of money for fixed charges, fuel, supplies, and labor. In many cases his steps toward greater economy have been halted by the limitations of construction and the properties of his materials.

Carnot has shown that in order to get the greatest thermal efficiency from a machine using heat, all the heat must be added at a constant temperature, and that all heat taken from the device must be removed at a constant temperature. In such cases the thermal efficiency becomes

$$\frac{T_1 - T_0}{T_0} = 1 - \frac{T_0}{T_1}$$

This efficiency is less than unity by the fraction T_0/T_1, which becomes smaller as we increase T_1 or decrease T_0. Hence the temperature T_1 must be made as great as possible and T_0 as small as possible.

To study the effect of the different ways in which heat may be used on any cycle the temperature-entropy diagram has great value, because on such a diagram areas beneath lines represent heat added. If there is no friction the addition of heat is from the outside. On this diagram, Fig. 1, horizontal lines represent isothermal action and vertical lines reversible adiabatics on which the entropy is constant and below which there is no area and consequently this action takes place with no addition of heat. The Carnot cycle becomes a rectangle.

In this diagram of temperature and entropy coördinates the liquid line for one pound of water and the dry saturation line for one pound of steam are drawn from tables of properties of steam. A path representing the addition of heat to form one pound of steam at 350 lb. absolute pressure from water at 70 deg. fahr. is shown by the area *abcdefa*. If this steam is put into an engine or turbine and expanded adiabatically to 70 deg. fahr. the steam expands along the line *de* and exhausts into the condenser, the heat given up being represented by the area *febaf*. The difference between the heat added to make the pound of steam and put it in the engine or turbine and the heat rejected from the turbine must represent the theoretical work obtained because the pound of water is again at its original condition *f*. (A small amount of pumpage is here neglected.) This work is represented by the area *bcdeb*. The efficiency is given by the ratio of areas $\frac{bcdeb}{abcdefa}$. If the same amount of heat were added on a Carnot cycle the slanting line *bc* would have to be replaced by the line *gh* so that *ihdfi* would equal *abcdefa*, and the work would be increased by *khc* − *kbg*. The efficiency would then be $\frac{hdegh}{ihdfi} = \frac{de}{df} = \frac{T_1 - T_0}{T_1}$.

[1] Dean of the School of Engineering, Princeton University. Mem. A.S.M.E.

The cycle *bcdeb* has been called the Rankine cycle with complete expansion, and represents the heat transfer of the theoretical cycle of the steam turbine. The reason for its efficiency being less than that of the Carnot cycle is due to the fact that all of the heat has not been added at one temperature. The heat added from *b* to *c* has been added at a varying temperature, resulting in the loss of the corner *blc* of a rectangular Carnot cycle, and it is evident that any substance which has a steeper liquid line than *bc* would give better efficiencies. It may also be seen that any substance in which the length of the line *cd* from liquid to dry saturation is greater than that shown for steam will give a higher efficiency at the same temperature limits as the ratio of the lost triangle to the remaining area is smaller. It approaches more nearly the Carnot cycle, which is the perfect cycle. Of course it is theoretically possible to have a regenerative heating cycle of an infinite number of steps in which steam is taken from the turbine and used for heating. In this case the line *de'* becomes similar to *bc* and the heat required on *bc* is removed from the working medium within the apparatus on *de'*. In this case all outside heat is added at one temperature and removed at one temperature, thus resulting in an efficiency equal to that of the Carnot cycle.

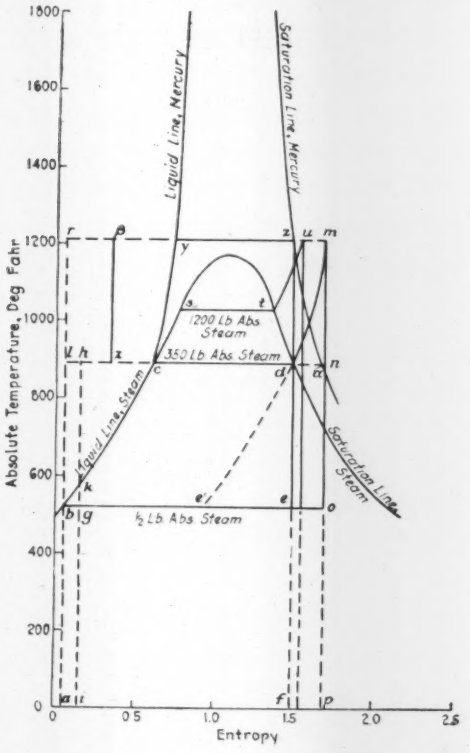

FIG. 1

To increase the efficiency of the cycle it is necessary to raise the highest temperature of the cycle so as to make the line *cd* higher and thus utilize a greater fraction of the area beneath the top line, since the line *eg* is fixed by the temperature of condensing water. Until quite recently it was thought inadvisable to raise the line *ed* at 350 lb. and 432 deg. fahr., because with a slight increase of temperature there was a great increase in pressure and hence the increase of range of temperature was obtained by superheating this steam at 350 lb. to a higher temperature, say, 750 deg. fahr. This action changed the point *d* to *m* along the superheating constant-pressure line to *m*, giving the area *abcdmnopa* as the heat added and the useful work *bcdmnob*. On account of the lengthening of *cd* to *cn* the percentage of triangular loss *bcl* became smaller and the triangular area *dmn* is added to the work and also to the heat, having the greater percentage effect on the work. For these two reasons the theoretical efficiency has been increased, but the additional heat represented by *fedmnopf* has been added at a varying temperature. To have had the full value from the increase of temperature range the cycle should have been *brmob;* the possibly usable area *lrmdl* has been unavailed of because of the nature of the substance and its application. The efficiency is now far from the Carnot efficiency found from the limiting temperatures.

The high-pressure turbines using 1200 lb. have extended the pressure line to *stu*, using part of this area previously unused. Even here the unused portion represented by the triangular area above the liquid line is made greater.

For the purpose of using this waste area to better advantage Mr. W. L. R. Emmet has proposed to use mercury between the high temperatures possible with present-day materials and the temperature of exhaust which does not give too great a specific volume of mercury and gives saturated steam at a convenient high pressure.

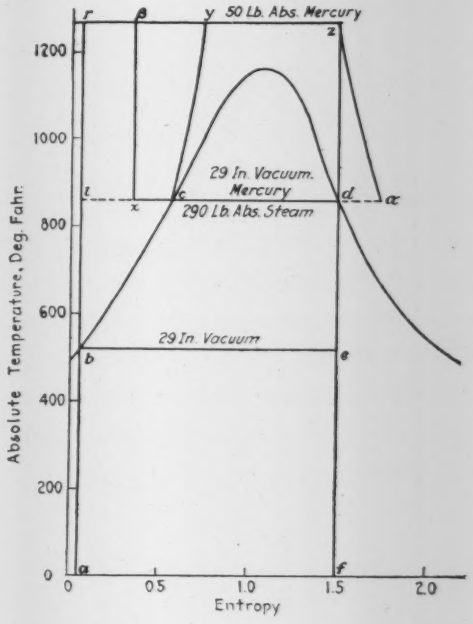

FIG. 2

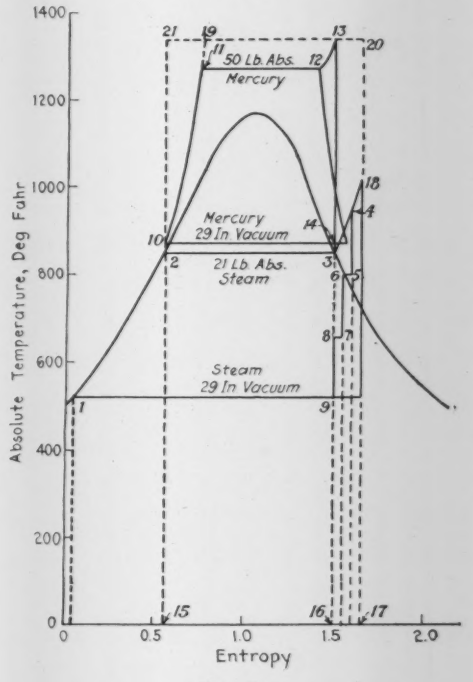

FIG. 3

Then he uses the heat abstracted by the condensation of the mercury to make steam which may be used in a steam turbine and condensed at the low temperature of the cooling water. As seen by the properties of mercury presented in an excellent paper on the mercury turbine by William J. Kearton before the Institution of Mechanical Engineers and published in *Engineering* for November 23 and 30, 1923, the lower heat of vaporization of mercury means that for one pound of steam evaporated from *c* to *d*, several pounds of

mercury must be condensed. If, then, the entropy of this number of pounds of liquid mercury at the temperature of c be laid off from c to give the point x of zero entropy the liquid line cy can be drawn for this number of pounds of liquid mercury, and dz will give the reversible or non-frictional adiabatic of mercury, the dry saturation line being $z\alpha$.

If these theoretical cycles are redrawn, Fig. 2 results. In this figure the only loss from the Carnot cycle is the triangular area $bcyr$, and the theoretical efficiency is increased because we have added more heat at the highest temperature—in fact, most of the heat instead of a very small portion if we use waste heat for liquid warming. It is to be noted that the nature of mercury is such that the liquid line is much steeper than the liquid line of water, thus cutting down the triangular loss and suggesting the use of the mercury to as low a pressure as convenient in the design of blades. Moreover the ratio of the length line yz to $y\beta$ is much greater than that of cd to cl. For both of these reasons mercury is a better substance thermodynamically than water at these points.

The theoretical diagram used in the actual installation has certain differences from Fig. 2, which will be mentioned.

1 The mercury will always be condensed at a temperature slightly above the temperature of the steam formed to give heat flow, hence the line cd for mercury is separated from that for steam.

2 It may be advisable to use some superheat of the mercury to eliminate the effects of wet mercury vapor.

3 The waste fuel gases after leaving the mercury boiler may be of such a temperature that they can be used to superheat the steam made by the condensation of the mercury.

4 If economizers can be used on the boiler feedwater or mercury, then part of the heats under the lines bc or cy may be saved; or if this heat in the gases is used to preheat the air entering the furnace, then the regenerative cycles may be used and the heat under the liquid lines may be applied by bleeding, which has been represented as taking place for steam in three stages in Fig. 3.

Work = 1-2-3-4-5-6-7-8-9-1 + 10-11-12-13-14-10

Heat Supplied = 15-10-11-12-13-14-16-15 + 16-3-18-17-16

$$\text{Efficiency} = \frac{\text{Work}}{\text{Heat}}$$

Unapplied Area = 10-11-12-13-21-10 + 3-13-20-18-3 + 2-10-14-3-2

The proportional unapplied area is much smaller than in other combinations and as a result the efficiency is greater. The reason for this is the fact that more heat has been added at a higher temperature than can be applied in cycles using a single fluid, water.

It is also to be noted that the secondary fluid water is necessary because of the exceedingly low pressure and enormous volume which would result if the mercury were carried to the temperature of the cooling water.

A Résumé of Recent Power-Station Developments

BY JOHN H. LAWRENCE,[1] NEW YORK, N. Y.

THE Power Division of The American Society of Mechanical Engineers has devoted practically its entire attention during the last year to the subject of power generation in its various phases. Papers on steam and water power were discussed at both the Spring and Annual Meetings of the Society, and also at Regional and Local Section Meetings.

There is no field in engineering in which changes come more rapidly than in power-plant engineering. In fact, it can be truthfully said that the modern plant of today is obsolete in many respects before it is actually placed in commercial service. This is not due to negligence on the part of the designer, but rather to the tremendous strides being made in the development of new ideas concerning improvement in efficiency and safety of operation.

Much thought has been devoted during the last year to the study of heat cycles and higher pressures and temperatures. This fact was attested to at the Annual Meeting when a very successful session was held on these subjects. It is clearly apparent that the so-called Rankine cycle is rapidly losing its place in steam power plants in favor of the regenerative cycle. All manufacturers of large turbines are designing their units so that steam may be bled at one or more points. The use of extremely high pressures has brought with it an added complication in that the dewpoint is reached earlier in the expansion of the steam through the turbine, resulting in the addition of reheaters in some of the plants now being built.

Several stations are now being designed to utilize pressures of from 550 to 1200 lb., and within a year we can expect to receive information concerning their operation. Up to the present time none of these stations contemplates over 750 deg. fahr. as the maximum temperature. Availability of suitable metals is still the limiting factor in the use of higher temperatures.

The Benson 3200-lb. pressure plant is now under construction in England. In this plant the steam will be generated at the critical pressure; that is, at the pressure where steam and water have the same density and no latent heat is required. The steam will be throttled to 1500 lb. before entering the turbine.

Except in a few isolated cases there has been no marked tendency toward an increase in size of boiler units. Practically all large stations are being designed for boilers of from 1500 to 2500 hp. capacity. Probably the most startling departure in boiler design has been the introduction of water-cooled furnaces; that is, lining the walls with water-tube surface as an integral part of the boiler circulating system. Several large stations have adopted this idea and tests are now being made to determine their effect on combustion and maintenance. Excessive deterioration of furnace brickwork has limited the use of higher furnace temperatures and also the use of more than moderate preheating of the entering air.

The subject of air preheating had received very little attention in this country until quite recently. However, considerable interest has been aroused in the last year and many installations are now being made, but unfortunately very few reliable data are available.

There has been very little change in the last year in equipment for the burning of coal. Stoker manufacturers have brought out no radical departure from past practice, and this may also be said for pulverized fuel. While many installations of the latter have been made, nevertheless the stoker has still retained the confidence of many engineers, and it will probably be many years before either system attains a supremacy over the other. In justice to pulverized fuel it should be stated that this system is comparatively in its infancy so far as steam power plants are concerned, and for it considerable improvements are predicted.

The development of larger boilers has brought about a change of design in superheaters. With the increase of water-heating surface exposed to the furnace temperature, it has been found impossible to secure high superheat on horizontal water-tube boilers with the superheater in the former standard location above the tube bank. Superheaters located in the tube bank have given a much more uniform temperature than in the former location.

It is probable that with the further increase of water surface exposed to the furnace temperature, that is, with a water-cooled furnace, it will be necessary to use some form of radiant superheater. Considerable development has taken place along this line, particularly with pulverized fuel.

Much interest has been aroused during the past year in automatic combustion control. There seems to be a fairly marked divergence of opinion among engineers as to the method to adopt, and consequently we may expect to see at least five or six different systems tried out in large stations during the coming year.

Turbine manufacturers are keeping pace with the increase in

[1] Engineering Manager, Thomas E. Murray, Inc. Retiring Chairman, Power Division, A.S.M.E.

size of stations by offering larger generating units, in some cases with capacities of 75,000 kw., but none of these has been purchased. Several units of 50,000 kw. on one shaft are now being installed and will be in service before summer. The use of high pressure and temperature has led most manufacturers to build cross-compound units. In one station three machines of as many makes are to be of this type.

There have been no striking developments in condensers and auxiliaries during the past year. Single-pass condensers have received considerable attention from operators and one large company has contracted for two such units of approximately 30,000 sq. ft. surface, each to be used in connection with two 35,000-kw. units. Although it has not been demonstrated that the steam-jet air pump for condensers is more efficient than the earlier types of pumps, still this unit is rapidly gaining favor because of its compactness, freedom from moving parts, and ease of operation.

One very beneficial result of the intensive study which has been made of power-house design in the last few years has been attention devoted to efficiency of auxiliary units. A kilowatt saved in auxiliary power is a kilowatt that can be sold without increasing the fuel item.

Since the announcement of the idea ten years ago, engineers have awaited with great expectations the first commercial installation of the mercury boiler and turbine. This has recently been completed and is now in regular operation. In this installation the mercury is boiled at 35 lb. pressure and approximately 800 deg. fahr., and after passing through a turbine is condensed in a steam boiler, the resulting steam being used in a steam turbine. This system is the most radical change that has ever been brought out in power-station design and the operating results will be looked forward to with great interest.

A number of installations of closed systems of cooling generators are now being made by various manufacturers, but at the present time very little accurate operating information is available. However, a number of tests will be made during the present year and it is to be hoped that data on the subject will soon be furnished to our members. One difficulty has been encountered in several stations. The amount of condensate available for cooling water has been so materially decreased by increased efficiency of turbines and by bleeding that in practically every case it has been found necessary to provide additional water from other sources. This is not always available, especially along the coasts and in other places where suitable water is not readily obtainable at reasonable cost.

Considerable development work is now being done on low-temperature distillation in connection with power plants, and installations are now being made. The Power Division will present the results to its members as soon as they are available for publication.

The Power Division has been keenly interested in hydroelectric development and many meetings have been devoted to this subject which is now of national importance. Interconnection of electrical systems has resulted in more economical utilization of our natural resources by the proper distribution of load between water and steam plants. One meeting was recently devoted to methods of determining the water flow to hydro units.

Water-turbine designers have also kept pace with the increase in size of hydro plants. The largest turbine ever constructed, 70,000 hp., was placed in operation at Niagara Falls in December. The largest propeller-type wheels, 30,000 hp., are being constructed for a Canadian station, and 35,000-hp. Francis-type turbines for a head of 850 ft. are now under construction.

The improvements in the design of full automatic stations of small size have given impetus to the development of streams which would not otherwise be economically possible.

Education and Training for the Industries

Report of Conference on the Subject, Held at the A.S.M.E. Annual Meeting—Address by Dean R. L. Sackett on Industrial Education in Great Britain

THE Conference on Education and Training for the Industries was held at 2 p.m. on December 5, 1923, as part of the program of the Annual Meeting of the Society, with President-Elect Fred R. Low in the chair. No general invitations to attend the conference had been extended, and it had been assumed that about forty persons would be present. But ninety members, all that could be admitted, were actually in attendance. The conference was very representative, both of a variety of industries and of educational interests, and was marked by considerable interest and enthusiasm.

President-Elect Low first called upon Dr. Ira N. Hollis, President of Worcester Polytechnic Institute, to review the work of the Society's Committee on Education and Training. Dr. Hollis stated that this Committee was confining itself in its investigations to education of non-college grade for industry, in contradistinction to the work of the Committee on Relations with Colleges.

Dr. Hollis laid great importance on the value of industrial training of non-college grade, deprecated strongly the use of the term "below college grade," and stated that the main object of the Committee and of the Conference was to arrive at mutual knowledge, mutual understanding, and coöperation between The American Society of Mechanical Engineers and all trade schools, technical institutes, and other schools engaged in this important work of industrial training. In the course of his address, Dr. Hollis said:

> College education is really a small part of the education for the industries of this country. It is not often that we quite realize that after all government and progress is to a large extent an economic question, and upon the proper solution of our economic questions of the United States will depend the permanency of this republic..... I find that the cause of the complete failure of the Greek civilization was the fact that no man who worked with his hands, no man who engaged in his trade, was permitted to vote.....
>
> Here are eighteen thousand men of a professional grade, many of whom have great influence in the industries, occupying commanding positions therein. What can we and they do to add to the dignity of the work that is done in the industries, and add to the knowledge of this country as well as our own membership as to the pathway through which men must pass to enter the industries?..... The success of anything of the kind, our little share of it, is going to depend upon very close coöperation with all of the organizations that are working toward the same end, and that is what we hope for..... I know that this training for men to do better work is bound to make better citizens, and it is in that hope that this committee of The American Society of Mechanical Engineers has come in here for a plain talk with other men interested in the same field.

Dean R. L. Sackett, of Pennsylvania State College, then made a very pertinent address on the influence on industrial training of courses in British institutions where a degree is not given or of courses which are not used toward a degree. Several British institutions have municipal schools of technology associated with them which give instruction in day and night classes. Others do not give a degree but provide instruction of a wide range from trade courses up to those of college caliber. The text of Dean Sackett's address immediately follows.

Industrial Education in Great Britain

By ROBERT L. SACKETT,[1] STATE COLLEGE, PA.

IN GREAT BRITAIN there is an interesting group of schools known generally as "polytechnic institutes," which do not give degrees but offer a wide variety of trade and engineering instruction in both day and evening classes. They are under either municipal or private control, or dependent on local taxation and student fees or on endowment and student fees. These are in addition to the manual-training technical high schools and the continuation type of school. In fact the school system of Great Britain has expanded very much in the last few years, and the most modern provision is being made for the education of the industrial worker in order to maintain the supply of the necessary skill which English methods

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require. Unquestionably they have produced and are prepared to produce skilled mechanics, and the men in charge of production, erection, and operation are more generally men of skill in the work of those under them than is the case in the United States. There may be exceptions, but in general this seems to be true.

Northampton Polytechnic Institute, London, will serve as an example of a school which does not award a degree, and yet those who pursue its engineering courses to their completion are eligible to take the examination of the University of London for a degree or to take the examination for membership in the Institution of Mechanical Engineers. On the other hand, it is a high-grade "practical" school and gives instruction in not only engineering lines but also in telephone, telegraph, cable construction, and radio for those in or proposing to enter the post-office department of the government. There are courses in optics and in the construction of optical instruments, glass working, fuels and combustion, electroplating, electrotyping, metal finishing, and watch and clock making. There is a wide variety of subjects offered for apprentices, fitters, lathe hands, machinists, patternmakers, molders, finishers, smiths, tool makers, oxy-acetylene cutters and welders, electrical wiremen, electrical workers and many others. It has about 5000 students in evening classes and 500 in day classes. The laboratories compare well with the best in Great Britain and the instruction is of high grade. The polytechnic institutes also give instruction to women in domestic science, millinery, cooking, laundering, dressmaking and related subjects.

There is still another group of institutions maintained by the London County Council known as "junior technical institutes;" these lay the foundation for an industrial education, which can be continued by attending one of the polytechnic institutes.

The Fisher Bill passed by Parliament in 1918 provided for a national system of continuation schools for employees between the ages of 14 and 18. The program called for a gradual increase in the number required to attend, and in 1925, when the act will be in full operation, it is estimated that 1,200,000 young employees will be in attendance for two half-days per week.

Apprentice training has been continued in Great Britain and is still a factor in the production of a supply of skilled workers. The old method has been supplemented by attendance at continuation schools and by organized instruction within the works. One large company in normal times gave five hours of class instruction per week to all apprentices, on company time, and also supplied books and materials.

Most of the large corporations employing technical graduates have systematic instruction for them. The plan is in general similar to that practiced here of rotating the students through various departments of the works and giving class instruction in parallel with his work.

In general, Great Britain has provided a rather complete system of industrial education with the common schools, continuation schools, local technical schools, the polytechnic institutes, and the excellent colleges and universities. Apprentice training is more general and is stressed more there than here. As a result of these factors and the general attitude and traditions of British industry, they are probably doing more to maintain the supply of skilled men than we are. American industry has been depending to some extent on immigrant mechanics, but the supply is now much reduced and it seems desirable that American industrial executives should concern themselves with the adoption and support of continuation schools, technical or junior high schools, and systematic works schools for the training of men on whom they must depend for skill and special knowledge not obtainable outside the industry.

Let us not forget that the old guild schools were the original trade or practical schools for the training of craftsmen. They were the earliest institutes for the training of manual, mechanical, and arts craftsmanship. They antedate technical colleges by centuries, and through the Middle Ages they kept alive pride in skill and held aloft the torch of beauty in utility.

Instead of increasing in number, schools to perpetuate these age-old traditions have become relatively fewer. The age of power and labor-saving machinery apparently led many to believe that the need for skilled men had passed. The old apprentice system has gone. Society has overemphasized the social status of the white collar. The dollar standard has been substituted for the quality standard. Pride in individual production has been traded for a standardized wage. The development of science has given a tremendous emphasis to scientific attainment, and very properly so, but we have lost sight of the fact that this same technical expansion has added to the scope of human effort and has not substituted the highly skilled technician for the practical man. The trained, practical man is even more necessary than in ages past and we are now awakening to this fact. The industrial manager seems least aware of this need, and even now is a party to the conditions which we face in the trades.

The educator seems also to neglect three-fourths of humanity in his school plan. It is obvious that not all can learn technical theory by the usual methods of school and college instruction. Many, probably the majority of humanity, are eye-minded and must learn, or learn best, by seeing and analyzing afterward. Some are going to college who ought not to go, and some are not going who ought to go. The fact remains that many are not going who are potentially skillful if the right method of developing their abilities is offered them. There are very few trade and practical schools in this country, and some of them desire to be colleges rather than to do the work which they can do and which no one else is doing. I am urging that they take as much pride in their work and develop the same esprit and class consciousness as the colleges have developed.

We need the colleges, but we require also the polytechnic institutes of Germany, Great Britain, and the United States. We need to reëmphasize the social dignity of, and the social service performed by, a skilled plumber, mason, machinist, electric wireman, steam fitter, engine or motor operator, and the many other craftsmen needed to support our complex civilization. As a part of our national school system and our industrial training within the industry we need organized instruction adapted to the varied character of our citizenship and to the diversity of our social and industrial life.

Consciousness of a need precedes the demand for an article. We lack consciousness of the economic value of training as a substitute for the obsolete apprentice system. We bewail the lack of artisans and do nothing to train a supply. The law of supply and demand is not always an adequate remedy when artificial restrictions have been imposed on it. The industrial, construction, and transportation interests and society at large need to revalue skill and to recognize the dignity of the laborer who applies the limit of his capacity to his job. They must realize the need for and support *all* the agencies which can and do contribute effective aid in the development of manual and mental skill, craft consciousness, and pride in individual production. The times are out of joint; there is social injustice in wages paid and not paid; in opportunities given and withheld. These are causes contributing their part to destructive social movements. There is but one remedy and that is and has always been education; not education for a class, but education of kinds adapted to human capacities and human needs.

Further Proceedings of the Conference

THE speakers who followed Dean Sackett early in the meeting were Prof. Dugald C. Jackson, of the Massachusetts Institute of Technology, a member of the Committee on Education and Training, and Dr. C. R. Mann, of Washington, D. C., Chairman, Civilian Advisory Board, War Department.

Professor Jackson emphasized the importance of a more effective training for the artisanship of the land, and said that he used the word "artisanship" with the greatest recognition of its dignity and importance. Dr. Mann thought that it was very important to make clear to the public that "less than college grade" is not a title of inferiority. This feeling of inferiority was even regrettably evident among the instructors in industrial training themselves. Dr. Mann also thought that there was another aspect of industrial training quite as important as its purely vocational character, namely, that it was a training for citizenship.

The Chairman of the Committee on Education and Training, Prof. J. T. Faig, President of the Ohio Mechanics Institute, Cincinnati, wishing to draw into the discussion men who represented industry, then called upon Wm. E. Wickenden, Director of Investigations, Society for the Promotion of Engineering Education. Mr. Wickenden doubted whether non-collegiate training had been

sufficiently dignified in the United States, and at the close of his remarks said:

> This is a subject about which our achievements are not, in the main, creditable to us, when compared with the European nations; and important as the subject is of strengthening the professional preparation for the industries which is given by the colleges of education in its magnitude and possibly in its importance, this problem of professional education of a subcollegiate grade is the immediate and burning issue of our educational problem in American industry.

Luther D. Burlingame, of the Brown & Sharpe Mfg. Co., Providence, R. I., pointed out that there were two sides to the question: First, young men in the shops must be provided with educational advantages to give them an opportunity to advance. But the second point was to get into the minds of the rising generation of young men the fact that an industrial life in the factories was a worthy and proper life for a young man to look forward to, not merely a stepping stone to an executive position. We needed scientific mechanics, the backbone of our industries. Mr. Burlingame closed his remarks by introducing the following resolution, which was adopted:

> *Resolved*, That this Conference requests the A.S.M.E. Committee on Education and Training for the Industries to prepare a plan for a careful study of the character and extent of the education and training of the non-college types which will be most serviceable to the industries and society of this country, and to circulate the plan among the organizations most interested.

L. L. Park, of the American Locomotive Company, told the Conference that study of the matter of apprenticeship by the American Management Association had brought forth the conclusion that many business organizations were making no effort to train employees. Smaller industries were particularly at fault in this regard. Mr. Park thought that the public schools should coöperate more closely with industry in this matter of training. E. C. Clark, of the Chambersburg (Pa.) Engineering Company, described how his Company had finally secured the coöperation of local school authorities in the training of its apprentices; how subjects of minor importance in production such as economics and English were finally eliminated; and how the local school instructors had to be themselves trained in the production methods of the engineering company.

M. R. Lott, of the Sperry Gyroscope Company, Brooklyn, made the following valuable remarks:

> One of the things that struck me particularly in answering the questions from some of the local schools in Brooklyn as to how they might train men for the industry, is that we don't have a common understanding of what the trade requirements are.... If local schools are to train for industry or to help industry, there must be a better understanding of what the different requirements are. And it is perfectly possible to derive specifications which will give that very explicit information.

G. M. Eaton, of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa., said that in their training schools they tried to produce good draftsmen, to instill the pride of craftsmanship in their men, but they also tried to promote from their junior ranks and convince their men that there were many opportunities for rising. G. H. Pfeif, of the General Electric Co., also emphasized the importance in training young men engaged in industry of showing them the possibility of better things.

W. G. Furer, of the American Locomotive Company, liked to have every apprentice taught that it was love of the work itself that would be his reward, not merely the wages. J. F. McIntyre, of the United States Radiator Corporation, said that if the manufacturer would take a little more interest in the boy during his sophomore and junior, or between his junior and senior year in high school.....it would increase his interest in an industry, and he would have something definite to strive for.

George B. Thomas, of the Western Electric Company, describing training methods in that organization, said that they always tried to fill vacancies by promotion and trained their men with this in view. A regular systematic course was provided for young men: six hours a week in fundamental mathematics, physics, and electricity and magnetism. The evening work was a stepping stone to promotion, and could be followed by more advanced training. A. T. Koehler, of the Joint Conference Committee of the National Industrial Conference Board, and of the Society for Promotion of Engineering Education, said that in his experience it was hard to sell to small businesses the idea of industrial training—businesses for which this involved financial strain. Industrial undertakings should also find out exactly what they needed so as to give outside school instructors a very definite idea of their requirements, to relieve them in the present congested system of educational work.

A. L. Williston, Principal of the Wentworth Institute, Boston, and formerly Director of the Pratt Institute, Brooklyn, was of the opinion that the tremendous labor turnover in industry was due to the fact that young men were given too few opportunities to learn and improve. The thought that the preference for "white collar" occupations was solely on this score. H. J. Hansen, of the Bridgeport Trade School, Bridgeport, Conn., J. A. McCarthy, of the State Department of Education, of New Jersey, and F. E. Mathewson, of the Dickinson High School, Jersey City, discussed the problem from the point of view of the trade school, and of the difficulties involved in vocational training, particularly in getting boys to train for trades rather than for "white collar" occupations.

New 60-In. Telescope for Perkins Observatory

(Continued from page 117)

tube than for the other combinations. Because of this it has been a custom in other large telescopes to provide a tube of this maximum length. In the Ohio Wesleyan instrument a design was worked out whereby an attachment easily installed at the upper end of the tube was provided for this combination. For the remaining optical combinations this extension is not needed and is therefore removed, thus materially reducing the length and increasing its convenience in handling.

A new departure has been accomplished in placing all motions in right ascension within the driving-clock unit. In other telescopes of this size and larger, a considerable part of this mechanism has been placed in the lower pier head with separate motors connected by a system of gearing to control the axis. Similarly, the declination motions have been condensed in the large housing at the outer end of the declination axis, thus eliminating much of the complexity in this portion of a large telescope.

The elimination of all operation mechanisms from both north and south pier heads is regarded as a forward step since this has considerably reduced the size of these pier heads, improving the external appearance of the instrument as well as making all bearings of the polar axis readily accessible. Extensive provisions for grease surrounding all bearings is an improvement which will tend to eliminate many of the difficulties experienced in telescope maintenance. The element of lubrication has been one of universal trouble in the efficient operation of telescopes ever since the beginning of the art. For some unexplainable reason the two subjects of astronomy and lubrication have never seemed to work together.

Except for a few elements of the telescope, the problem of machining and construction is not greatly different from that of any ordinary large piece of apparatus. The instrument maker's skill has to be relied upon first in the construction of the entire driving clock, for this element must operate with maximum efficiency and with no periodic error. For this reason it is necessary to pay the greatest attention to the machining of its component parts and to assembling these parts so that all bearings may operate with the least possible friction. Ball bearings are extensively used in the driving clock, and the seats for these bearings must be lined up with the greatest care. The cutting of the gears in the gear train is an operation which offers particular difficulties unless highly accurate equipment is at hand. For this purpose The Warner & Swasey Company has reconstructed a gear-cutting machine of their own design, the accuracy of which is far greater than that needed for ordinary commercial work. This machine is reserved particularly for the cutting of telescope gears and similar work.

In conclusion it should be stated that the United States leads the rest of the world in telescope development and design. While the first instruments were constructed many centuries ago by the earlier astronomers, it is an outstanding fact that improvements in design have nowhere been so evident as in our country. Not only does America lead in this branch of engineering but in scientific accomplishments, which by virtue of highly developed equipment, have placed her well ahead of other countries.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

The Efficiency of Steam-Turbine Nozzles

Second Report of the Steam Nozzles Research Committee of the Institution of Mechanical Engineers

THE first report of the Steam Nozzles Research Committee, published in the Proceedings of the Institution of Mechanical Engineers, No. 1, 1923, pp. 1–22, sets forth the considerations which led to the adoption of the lines of research which are now being followed. It also contains a description of the test apparatus and tables of the results obtained.

The method of test chosen was the measurement of the impact of a jet of steam, issuing from a nozzle, upon an impulse plate or cage. This cage was so designed that the momentum of the jet was all absorbed on impact and was arranged so that the steam could only leave the cage at right angles to the axis of the jet.

The chosen method of determining the efficiency of such steam nozzles as are actually suitable for turbines required the experimental determination of:

a The average actual velocity of the steam at or near the exit from the nozzle.

b The theoretical linear velocity of the steam at or near the exit from the nozzle.

The determination of these quantities is made as follows:

a The actual velocity c_m is obtained from the measurement of the discharge m and of the impulse F of the issuing jet against a pressure plate, the relation being

$$c_m = \frac{Fg}{m} \text{ feet per second}$$

where g is the acceleration due to gravity in feet per second per second. If the impulse is measured in pounds and the discharge in pounds per second, the velocity will be in feet per second.

b The theoretical velocity c of the steam is taken as that due to the adiabatic heat drop DH through the nozzle.

The adiabatic heat drop has been found to be:

$$\text{DH} = 0.4772\,(T_1 - T_2) - \frac{(c_1' - 0.0037)P_1 - (c_2' - 0.037)P_2}{2.2436}$$

To calculate values from this relation it is necessary to know the pressures P_1 and P_2 and the temperatures T_1 and T_2 on the two sides of the nozzle under test. The initial temperature T_1 and the two pressures are determined experimentally in a manner described in the Report. The value of T_2, or the temperature at the exit side of the nozzle, is arrived at theoretically from the fundamental adiabatic relation

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{3}{13}}$$

By writing the equation in the following form:

$$\log T_2 = \log T_1 - \frac{3}{13}(\log P_1 - \log P_2)$$

a convenient form for evaluation is obtained avoiding negative logarithms.

Having determined the heat drop in this manner, the theoretical steam velocity follows from the equation:

$$c = 300.2\sqrt{\text{DH}} \text{ feet per second}$$

when $g = 32.20$ ft. per second per second. Strictly speaking, this relation involves the assumption that the steam has no velocity before it enters the nozzle. In the present tests this condition has been met by the provision of a relatively large nozzle pipe to the underside of which the nozzle box is fastened.

The ratio of the mean actual velocity to the theoretical velocity is taken as the velocity coefficient ϕ, and the efficiency η of the nozzle is assumed to be the square of the velocity coefficient, or

$$\phi = \frac{c_m}{c}$$

and

$$\eta = \phi^2$$

In this connection it is important to bear in mind that the steam was superheated on both sides of the nozzle.

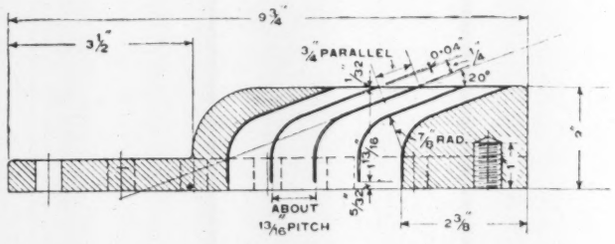

FIG. 1 CROSS-SECTION THROUGH THE IMPULSE NOZZLE USED IN THE STEAM NOZZLE RESEARCH TESTS

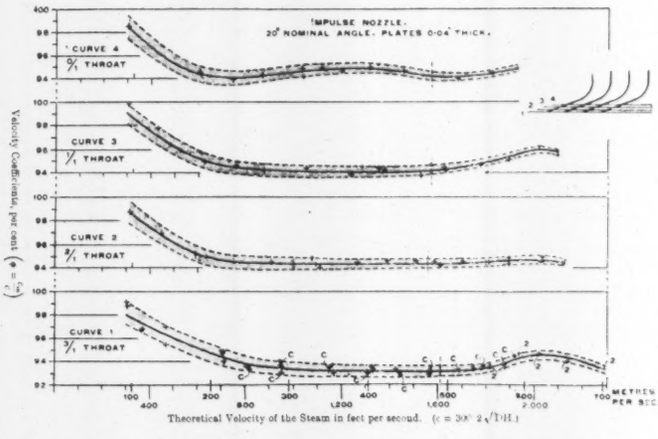

FIG. 2 VALUES OF VELOCITY COEFFICIENTS OF IMPULSE NOZZLES PLOTTED AGAINST CALCULATED THEORETICAL VELOCITIES

The report describes the method of test measurements and the preliminary tests. In all tests two nozzles were used—one impulse and one of the Parsons type. A cross-section through the impulse nozzle is shown in Fig. 1. The partition plates are only 0.04 in. in thickness and the length of the parallel portion of the throat is very great as compared with the throat opening, the ratio being three to one.

The values deduced for the velocity coefficients are shown plotted in curve 1, Fig. 2, against the calculated theoretical velocity. The parallel portion of the throat was then reduced 1/4 in. along the nozzle axis to give a ratio of parallel throat to opening of 2 to 1. The corresponding test results are plotted in curve 2 of Fig. 2. A third series of tests were then taken with a throat ratio of one to one, and a fourth set with no parallel throat at all. The results of these are shown plotted in curves 3 and 4.

The original report gives sample calculations of the various items, such as calculation of the actual velocity at exit, theoretical velocity

at exit, and velocity coefficient, which are followed by a discussion of the probable accuracy of the results. From all indications this latter was very high.

The efficiency tests of reaction nozzles were carried out on Parsons standard 480-B blading which was clamped with its own distance pieces into a nozzle box. The methods employed in these tests, while very interesting, cannot be described here because of lack of space, and only the summary and conclusion of the entire report will be presented. Further tests are in progress.

SUMMARY OF REPORT

The Committee believe that the results presented represent the first attempt to carry out on a full-size scale a systematic investigation into the efficiency of steam-turbine nozzles. The difficulties encountered have undoubtedly been serious, and have

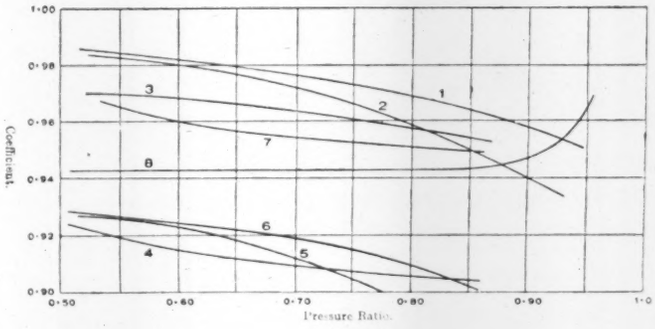

FIG. 3 NOZZLE COEFFICIENTS

(Nos. 1–7, coefficients of discharge; No. 8, coefficient of velocity.)

1	Loschge	Straight convergent nozzle, superheated steam
2	Gibson	Venturi-meter orifice, air
3	Mellanby and Kerr	Straight convergent nozzle with search tube, high superheat
4	Mellanby and Kerr	Convergent-parallel nozzle with search tube, high superheat
5	Loschge	Zoelly-type nozzle by flow ratio with convergent type
6	Anderson	Square convergent-parallel nozzle with search tube, high superheat
7	Anderson	Rectangular convergent-parallel nozzle without search tube, high superheat
8	I. M. E. Research Comm.	Impulse nozzle.

only been surmounted by recognizing limitations in the conditions of test. Such limitations should not be lost sight of when the results of this Report are discussed. In brief they amounted to:

1 *The Use of the Impulse Method for Obtaining the Thrust of the Steam at the Exit of the Nozzle.* This meant that, in the present tests, the central portion of the jet had traveled a distance of $2\frac{1}{2}$ in. from the exit of the nozzle before its thrust was recorded. Careful tests had shown that confidence could be placed in the correctness of this record as compared with the reaction method (to which a similar condition must pertain), but the fact remains that the thrust was not, and could not, be measured at the point where it would act in a steam turbine. However, by keeping the amount of free jet constant throughout, the tests of both impulse and reaction nozzles may be considered strictly comparatively, and the shape of each curve may be taken as representative for that particular nozzle type.

2 *The Use of Superheat on Both Sides of the Nozzle.* This was found to be necessary in order to insure that no moisture was present on the impulse plate and cage when the thrust was being measured.

3 *The Variation in the Initial Superheat.* This was brought about by the decision to maintain the exhaust pressure at or near atmosphere, which made for greater simplicity and therefore accuracy.

4 *The Use of Commercial Nozzles.* For both impulse and reaction types commercial nozzles with their attendant variations in finish were used, and no attempt was made to improve the steam passage or adjust any small discrepancies in dimensions. The only departure from standard was that the nozzles were mounted on a parallel instead of a circular base.

5 *The Use of Callendar's Steam Tables.* Although recognized as the most accurate and the only consistent set of steam relations, these tables are not the only ones used throughout the world. The numerical values and even the shape of the efficiency curves might vary if other tables were used.

6 *The Calculation of the Heat Drop* for the purpose of determining the theoretical velocity involved the accurate determination of the difference between two large quantities. This was one of the limitations which prevented the efficiency curves from being extended to lower velocities than 300 ft. per sec. in the present tests, and rendered the lower portion of the curve more inaccurate than the higher regions.

The efficiency curves obtained under such conditions as these may therefore be taken to represent, relatively, the behavior of such impulse and reaction nozzles between theoretical steam velocities of 300 ft. per sec. and 1980 ft. per sec., and, absolutely, the general shape of the curve between steam speeds. Owing to the fact that the impulse was not measured close up to the nozzle face, the actual numerical values for efficiencies in a turbine are not likely to be less than the values obtained, and may be slightly higher.

For the particular nozzles tested the efficiencies of a Parsons nozzle over the working range of modern reaction turbines may be taken as follows:

98.0 per cent at 280 ft. per sec.
92.1 per cent at 500 ft. per sec.
90.2 per cent at 700 ft. per sec.

For the working range of the impulse nozzle, say, between 980 ft. per sec. and 1300 ft. per sec., the efficiency is constant at 89.1 per cent.

The experience of the test brought out very clearly the importance of having no obstruction for the passage of the steam on either the inlet or the exit side of the nozzle if the best and most reliable results are to be obtained. On the exit side this reservation applied not only to any interference in the free blow of the jet after it left the tips of the nozzle partition, but also to flat surfaces in and below the exit plane. A complete series of tests were rendered abortive because some two inches of flat surface was left below the last nozzle of the first Parsons nozzles.

The angle of efflux of both Parsons and thin-plate 20-deg. impulse nozzles appears to be practically the geometrical angle of the nozzle close up to the face, but thick partition plates undoubtedly affect this angle to the extent of at least 2 deg. at or near the critical velocity, and very much more at larger pressure ratios.

The fact that in all the efflux tests an inward curvature of the center of the jet was found as the steam got further away from the

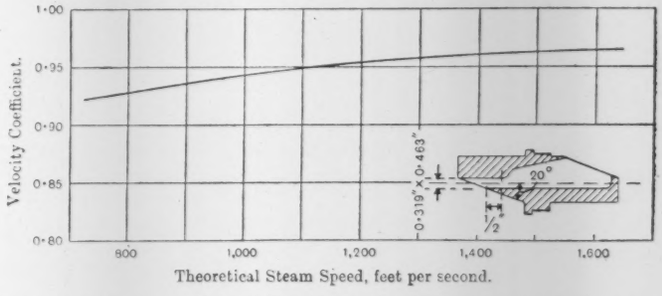

FIG. 4 VELOCITY COEFFICIENT FOR SPECIAL CONVERGENT-PARALLEL NOZZLE

point of exit, shows that the pressure is not constant across the face of the exit plane, but must be higher on the side which first leaves the partition.

DISCUSSION OF RESULTS OBTAINED

The report was the subject of an interesting discussion, from which only a few extracts can be given here on account of lack of space. David S. Anderson, in a written communication, pointed out that the type of test was not such as to lend itself to detailed analysis, and it seemed rather remarkable that the results of the tests stood practically alone and opposed to the results of the majority of previous investigations. He had gathered together some of these results and showed them in Fig. 3, along with the curve obtained by the Research Committee. It would be seen that all the previous investigators had obtained curves whose general trend was decidedly downward as the pressure ratio of operation increased. The curve form as presented by the Committee was quite flat over the corresponding region and then rose sharply at high pressure ratios. The fact that the Research Committee's curve represented velocity coefficients while the other curves were all discharge coefficients did not alter the comparison, since the downward tendency of the latter would have been equally well shown had velocity

coefficients been employed. To show that the falling coefficient was not characteristic of simple nozzles only, a curve of the velocity coefficient on a base of theoretical steam speed for an awkward-shaped nozzle was given in Fig. 4. It would be noticed that the falling coefficient was well maintained in that particular form. The method of testing this nozzle as well as the rectangular shape shown in the previous figure was by the pressure-flow method. In the absence of a search tube the pressures were obtained by means of fine holes in the nozzle walls.

While admitting the accuracy with which the Committee had carried out their tests, it seemed highly improbable that the possible lack of such fine limits in any of the earlier work had caused the investigators to obtain wrong curve forms. Even supposing that the degree of accuracy in any of the tests had been somewhat lower, it would only alter the absolute value of the coefficients and not the general trend of the curve. One was rather forced to the conclusion that it was the method of testing adopted by the Committee which was at fault. The impact plate was situated $2^1/_2$ in. away from the

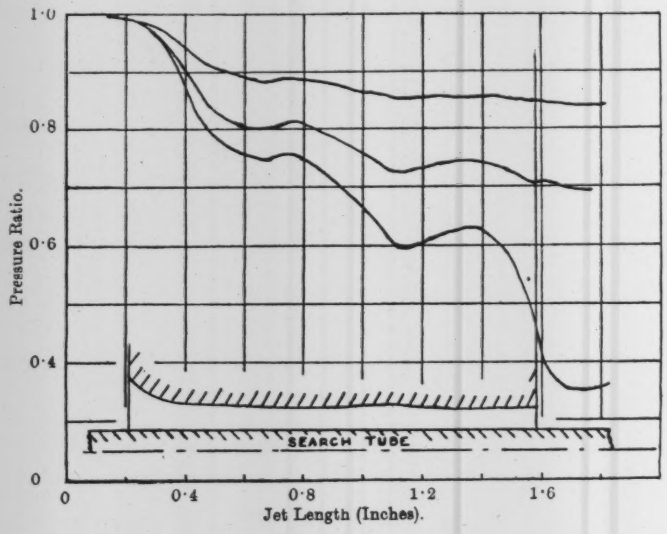

FIG. 5 PRESSURE-RATIO CURVES. CAST NOZZLE

center of the nozzle group. Two and a half inches of jet travel represented a very long time period on the scale on which internal jet actions took place, and it did not seem impossible that actions might have been going on here which obscured the true action taking place in the nozzle. Search-tube examination of many convergent-parallel nozzle jets had revealed the almost invariable presence of pressure waves in the region beyond the outlet. The establishment of such waves could not take place without affecting the jet to some extent, and it was just possible that the effect would be of such magnitude as to swamp any fine difference in true nozzle performance with changing conditions.

Alexander Cameron wrote that he had recently had an opportunity of making an extensive investigation of the friction effects in nozzles of a simple form, using the testing plant of the Royal Technical College, Glasgow. In the course of the work three convergent-parallel nozzles with different surfaces were tested. One nozzle had a highly polished surface; the other two were, respectively, machine finished and rough cast. At full range of operation the proportions of the total losses due to friction in the tail alone were for the three nozzles, respectively, 70.5 per cent, 85.2 per cent, and 87.6 per cent, the friction coefficients of the three being of the order 3, 5, and 14. These frictional losses varied with the length of the tail, but at a higher rate than the first power, since the pressure drop necessary to maintain flow in the tail also entered into the calculation. The accuracy of the above figures was at least within the limits which the Committee allowed themselves.

It would be seen that in each of these cases there still remained an important part of the total loss to be accounted for. There was evidence that, in the case of these simple nozzles, the remainder of the loss was entirely due to the form of the nozzle entry. In the case of the more complex nozzles tested by the Committee, other factors would probably also require to be taken into consideration. It was evident from the figures submitted that friction losses would alone require a greater difference in efficiency than obtained between curves 1 and 4 of Fig. 1, but accepting the figures in the report, it was obvious that an increase in the length of the tail of a practical nozzle had, for some reason, a beneficial effect.

It might be argued that a vena contracta effect, which admittedly existed at the throat, would operate to the outlet and thus prevent any friction loss. In this connection Mr. Cameron drew attention to the curves in Fig. 5, which showed the variation of pressure ratio along the length of the cast nozzle referred to. Highly superheated steam at an inlet pressure of 75 lb. per sq. in. was used in each case, the pressure at various points along the nozzle being obtained by means of a search tube. Supplementary tests showed that these curves were, within the limits of experimental error, absolutely definite for varying values of the inlet pressure. The different ranges of operation were obtained by variation of the back pressure. The tail was intended to be parallel, but the effect of the various imperfections in the casting had given to it the somewhat wavy form shown in the diagram. The nozzle was drawn in its correct position relative to the curves.

It would be seen, on comparison with the nozzle outline, how very sensitive the jet was to variations in the surface curve, and how closely it conformed to the nozzle area. These curves should show that any argument of the above nature, based on vena contracta effects, was at least highly improbable. The apparent benefit derived from the addition of a tail piece to a practical nozzle could therefore not be explained away on this basis.

Samuel Lees, emphasized the application of Gauss' Law of Errors through experimental work, and likewise the use of Bessel's and Peters' formulas for determining the probable error from a series of observations. This part of the discussion, while very interesting, is not suitable for abstracting. (*Proceedings of the Institution of Mechanical Engineers*, no. 3, 1923, pp. 311–395, 23 figs., *eA*)

Short Abstracts of the Month

CORROSION (See Special Processes)

ENGINEERING MATERIALS (See also Special Processes)

Some Extrusion Problems

THE information abstracted below is taken from an address by Major Sheppard at a meeting of the Birmingham Local Section of the Institute of Metals, December, 1923.

There has been a certain amount of prejudice in England against extruded rods, and only comparatively recently has the British Admiralty permitted their use. Some railway companies and other buyers still specify definitely rolled rods or prohibit extruded rods.

The quality of extruded brass bars depends first of all on good-quality castings. Surface defects must be practically non-existent.

One hears commonly of an extrusion defect resulting in the production of a hollow rod. This was supposed to be due to the actual flow of the metal during extrusion, but the author's experience was that the real extrusion defect was negligible and that the cause was a hollow casting or one that had not been properly fed.

The size and weight of the castings must, of course, depend upon the size of the extruding machine. As a rule this is fitted with changeable containers of variable sizes, enabling the use of billets of two or three diameters, for example, 4, 5, or 6 in., with a length of 18 to 24 in.

With regard to the soundness of castings the foundryman had sometimes broken a casting at the top to demonstrate its soundness. But this apparent soundness was often misleading, and a more satisfactory method of examination was to cut off a section from the billet near the top and roughly polish and etch it, when occasionally there would be discovered a minute trace of porosity in the center quite sufficient to cause hollowness in the bar. This was particularly the case with copper. In casting copper for extruding, minute details should be carefully attended to and elaborate precautions

taken to insure perfect homogeneity. The temperature of casting, method of deoxidizing, rate of pouring, temperature of ingot molds, and the method of feeding must be kept under most rigid control. The author's experience related chiefly to deoxidized copper rather than tough pitch copper, but he believed that extrusion of such copper was often done. Of this, however, several problems in connection with casting called for experimental work. He believed the general practice was to remove the top of the casting, which was bound to be more or less rough and dirty, but two or three inches should be sufficient. If that was properly done, no dressing or machining should be necessary.

The author discusses next the heating of the billet and the amount of pressure on the ram as well as the oxide problem. One of the other problems has to do with the mechanical properties of the extruded bars. During the process of extruding the billet was cooling in the container; consequently the front end of the extruded bar had to be worked at a considerably higher temperature than the back end, giving a marked difference in the result in regard to the mechanical properties of the two ends of the bar. This was clearly shown in the microstructure of the two portions. No remedy for this is suggested.

The extrusion of tubes presented special problems. A hollow billet was necessary which could either be produced by casting on a core or piercing a solid billet by means of a special tool on the ram of the extruding machine. Personally, the author found it necessary to bore the casting and machine it on the outside to remove defects. The billet was heated and placed in the container in the ordinary way, and a steel mandrel inserted in the bore and forced with the casting through the die.

The difficulty of skinning was chiefly a matter of pressure. The shearing off of the skin necessitated a considerably increased pressure, and for tubes, owing generally to the small-cross sectional area and the impossibility of employing a multiple die, the pressure required was usually much higher than for rods. The high pressure caused the metal to adhere very firmly to the steel mandrel, and in stretching during its passage through the die put a very high tensile stress on the mandrel, often severe enough to cause breakage. In one such case the breaking stress was 22 tons per sq. in.

So far as he was aware, no steel had been found to stand the strain when extruding brass tubes of 70:30 composition and similar alloys, and at the same time skinning them by the process referred to. The makers of extruded tubes were still waiting for a steel of that quality. Occasionally difficulty had been met with in keeping the tubes accurately to gage. But if the tools were accurate the fault was generally traceable to the casting.

For the best quality of tube the author did not advocate extrusion. For tubes in which thick walls, not too accurate, were required, it was suitable and a commercial proposition, but for copper or brass boiler tubes or condensers considerable advances were called for upon the present methods. A copper boiler tube could be produced from the solid billet pierced and drawn to its finished size in three drafts. Even if a tube from the extruding machine could be drawn to its finished size in one draft, the extra expense would more than balance the other two drafts in view of the extra cost of casting due to limiting the size of core, piercing, boring, and turning prior to extrusion. Unless the method was considerably improved he did not consider extruded brass and copper tubes for boilers commercially economical.

This is followed by a discussion of extrudable metals and alloys. (*The Metal Industry*, vol. 23, no. 25, Dec. 21, 1923, pp. 555–556 and 560, *p*)

FUELS AND FIRING (See Internal-Combustion Engineering; Gas Engineering)

GAS ENGINEERING

The Measurement of Power Gas

THE ordinary commercial gas meter is incapable of dealing with power gas on account of its heat and the dirt and tar which it contains. The volume passing through the gas main can be determined either by (1) estimation in the case of engines, (2) pitot tubes, (3) orifices, (4) venturi tubes, or (5) electro-flow meters.

As regards methods of estimation of the flow of gas from producers, the author mentions that by analysis for ammonia content and the carbon-balance method, and gives a complete calculation for the latter. The other methods are discussed in detail and when necessary illustrated.

An interesting method is that where electro-flow meters operate on the orifice principle. The hyperbolic elbow is the means adopted in the hyperbo-flow meter for obtaining the necessary pressure difference. The orifice principle is also used and the diagram in Fig. 1 shows its operation. The system of electrical contacts, however, is essentially the same for all types of electro-flow meters. Referring to the diagram, the mercury column forms part of an electric circuit which contains a fixed external resistance R_1 in series

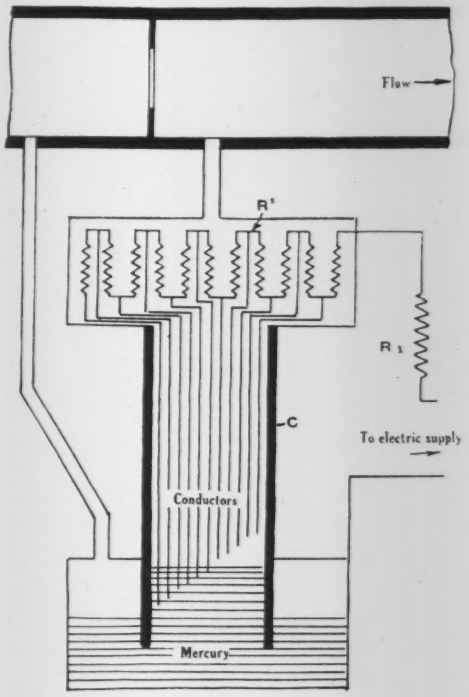

FIG. 1 ELECTRO-FLOW METHOD OF GAS MEASUREMENT OPERATED ON ORIFICE PRINCIPLE

with a variable resistance R^2. In contact chamber C which forms the low-pressure side of the U-tube, there are a number of conductors of varying lengths placed above a mercury column, and as the mercury rises it makes contact with one conductor after another. The variable resistance R^2 is subdivided by these conductors into resistance stops so that the rise and fall of the mercury column varies the amount of resistance, and therefore regulates the amount of current passing through the circuit. Moreover, the resistances are so divided that the flow of the current in the circuit is directly proportional to the flow of gas in the pipe, so that the electrical instruments provided, while measuring the current regulated by the flow, actually register the amount of gas passing through the pipe. The total amount of electrical energy measured by the wattmeter (not shown) is the exact equivalent of the total amount of gas passing through the pipe, accuracy being insured by using highly sensitive electrical instruments. The latter, of course, having no mechanical connection whatever with the meter body, are unaffected by temperature or dirt. (Maj. G. Johnstone Taylor, in *The Iron and Coal Trades Review*, vol. 107, no. 2913, Dec. 28, 1923, pp. 957–959, 9 figs., *d*)

Efficiencies in the Use of Bituminous Coking Coal as Water-Gas-Generator Fuel

CENTRAL DISTRICT bituminous coals have been used to some extent during the past few years in Illinois and the surrounding states as water-gas-generator fuel. The results obtained were encouraging enough to warrant further study of prevailing conditions and their causes, with the object of determining what changes in the construction of a water-gas set might be made to permit greater

economies in the use of bituminous coal as generator fuel. The desirability of making as few changes as possible and of using present equipment whenever it can be employed is recognized and has been kept in mind during the course of this study. High prices of oil and of coke and the tendency toward still higher prices increase the advisability of giving due consideration to this subject.

This paper is one of a series of publications dealing with an investigation relating to the manufacture of water gas. This investigation was conducted under a coöperative agreement between the Bureau of Mines, Department of the Interior, the State Geological Survey Division of the State of Illinois, and the Engineering Experiment Station of the University of Illinois.

Some of the data presented here have been published in other bulletins or technical papers of the Bureau of Mines. This duplication is made only when considered necessary to clarify the reasons for the conclusions reached.

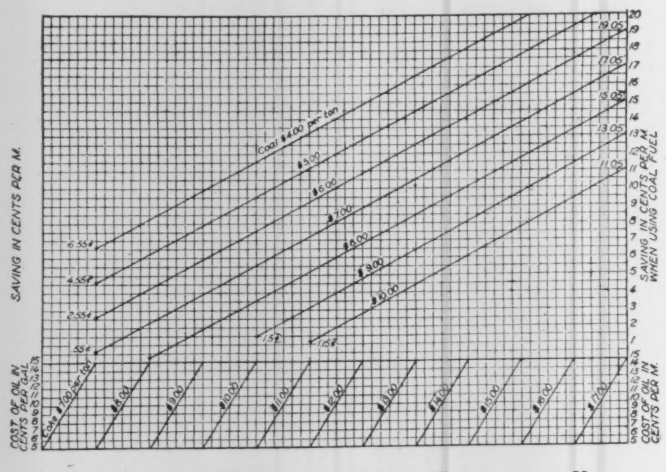
SAVING IN CENTS PER M.
Coal @ 4.00 per ton
6.55¢
4.55¢
2.55¢
.55¢
COST OF OIL IN CENTS PER GAL.
SAVING IN CENTS PER M. WHEN USING COAL FUEL
COST OF OIL IN CENTS PER M.

FIG. 2 CHART FOR DETERMINING ACTUAL SAVING FROM USE OF COAL FUEL

Because of lack of space only the conclusions of this investigation can be reported here.

At the present time, with the prevailing high price of coke, water gas can unquestionably be made from bituminous coal more cheaply than from coke.

As prices of coal and coke advance, with an increasing margin of difference between them, the economy that can be realized from the use of coal as generator fuel increases.

Fig. 2 is a chart from which the actual saving from the use of coal fuel can be quickly determined for any particular fuel when the coal, coke, and oil costs are within the wide range used in preparing the chart.

When coal is substituted for coke and the same methods of operating used as with coke, there is an appreciable waste of fuel, which can be eliminated.

The amount of this waste per thousand feet of gas made will increase as the standard of gas is lowered. The present tendency is toward a lower standard for city gas.

One method of eliminating waste—the use of a waste-heat boiler with combustion chamber—is suggested and discussed in this paper. The method is not offered as the only way or as the best way, but as a means to an end, with the hope that it will bring forth additional suggestions what will help to evolve a better method for accomplishing the desired results.

In figuring the benefit in dollars to be derived from the use of the waste-heat boiler, the aim has been to be conservative. The temperature—760 deg. fahr.—assumed for the waste gas leaving the boiler is perhaps high, and that of the gas leaving the checker chambers and entering the combustion chamber is low, giving a smaller drop in the temperature of the gases passing through the boiler than might be obtained in practice. However, this may be offset by the fact that the volume of producer gas may not be so great as figured, depending on the coal used and the method of operating. There is also a correction for moisture in the air and gas to be made in practice, which has not been made here for the sake of clearness. Moreover, with the existent variables, the exact radiation loss per thousand feet cannot readily be calculated. The cost of coal per ton (boiler fuel) is also intentionally taken at a low rather than a high value. The cost of the complete installation, as described, is greater than that of the present water-gas sets, hence in arriving at an exact net saving the interest as well as a larger depreciation charge will have to be taken into consideration. (Report by W. W. Odell in *Bureau of Mines Technical Paper*, no. 274, 1923, 39 pp., 1 sheet of drawings and 9 figs., *epA*)

HEATING AND VENTILATION (See Pipe)

HYDRAULIC ENGINEERING

A Miniature Water-Power Installation

DESCRIPTION of a plant having a capacity of 0.55 kw. at 85 volts, indicating what can be done to realize the potentialities of a mere trickle of water where the topographic conditions are favorable.

The turbine has a 4-in.-diameter, double-ended, compound-flow reaction rotor, the details of which are illustrated in the original article. It is mounted on a 3-in. oak bedplate molded into a concrete foundation. The generator runs at 1250 r.p.m. The compound efficiencies of the plant at various loads vary from 36 per cent at full load to 18 per cent at one-quarter load. The very low efficiency at low output reveals the great failing of the reaction type of turbine when employed on a system where every drop of water counts. It also shows that wherever a sufficient head of water is available an impulse wheel should be used.

The author states that the plant is perfectly reliable, the only involuntary stoppages, other than those due to failure of the water supply during the night, being in the early days of its installation; they were caused by the accumulation of air in the inner water-inlet cage, a trouble which was overcome by fitting a pipe outlet to atmosphere. The plant has many times run constantly for from three to four weeks, and occasionally six weeks, without even being inspected. Usually, the grease cups on the turbine bearings are given a turn about once a month, and the generator commutator is cleaned up at the same time. (D. C. Miller, in *Electrical Review*, vol. 43, no. 2405, Dec. 28, 1923, pp. 969–971, 6 figs., *d*)

Velocity of Flow in Pipes

AFTER briefly discussing several well-known methods of measurement of water flow in pipes, the author discusses the so-called color method, first suggested by Ribourt in 1903. A modification of this method was suggested in America and is at present being studied by Prof. Chas. M. Allen, Mem. A.S.M.E., of Worcester Polytechnic Institute. Here instead of a coloring material common salt is introduced either in solution or otherwise. The time of arrival of the salt solution at the lower end of the pipe is indicated by the reduction in electrical resistance between two electrodes fixed in the pipe in contact with the water. The time is measured from the introduction of the salt to the instant of minimum resistance between the electrodes. (Compare The Salt Velocity Method of Water Measurement, by C. M. Allen and E. A. Taylor, in MECHANICAL ENGINEERING, vol. 46, no. 1, Jan., 1924, pp. 13–16 and p. 51.)

The writer has carried out some experiments exactly on these lines, but the results have not been entirely satisfactory. He therefore adopted a modification in that the salt was introduced near the head of the pipe line and there were two pairs of electrodes relatively close to one another near the lower end of the pipe. By this means the salt would be thoroughly mixed with the water before it arrived at the upper pair of electrodes, and the time of mean passage of the maximum concentration of the salt between two pairs of electrodes could be easily determined by flow-meter observations across them. A favorable opportunity of making such an experiment occurred recently in connection with a water-turbine installation in North Wales, where there is a cast-iron pipe line having a total length of about 800 yd., part of which is 12-in. bore and part 9-in. bore. This pipe line is supplied from a reservoir and in its turn feeds two impulse wheels at each lower end, one a 12-in.-diameter Turgo impulse wheel and the other a 15-in. Pelton wheel. A rectangular weir without end contractions was fixed in the tailrace from the wheels. The flow of water into the reservoir was com-

pletely shut off. It was thus possible by means of the weir and by simultaneous observations of the drop in level of the reservoir to check very closely the measurement of flow obtained by the salt method.

The 12-in. portion of the pipe is at its upper end and the lower portion is 9-in. bore, all the lower lengths where the observations were taken being new. The salt was introduced about 20 yd. from the reservoir outlet; the lower pair of electrodes was screwed into the pipe just after it had entered the power house and before it reached the wheels, the upper pair being similarly fixed 32 ft. above. Direct current at 110 volts was available and leads were connected to each pair of electrodes through voltmeters. The electrodes used were ordinary spark plugs, slightly modified.

A saturated solution of common salt was made, the quantity introduced into the pipe for each observation being about one gallon. The time occupied in the introduction of the salt was about 5 sec. in each case. It was found that as the salt passed each pair of electrodes the corresponding voltmeter rose, slowly at first and then

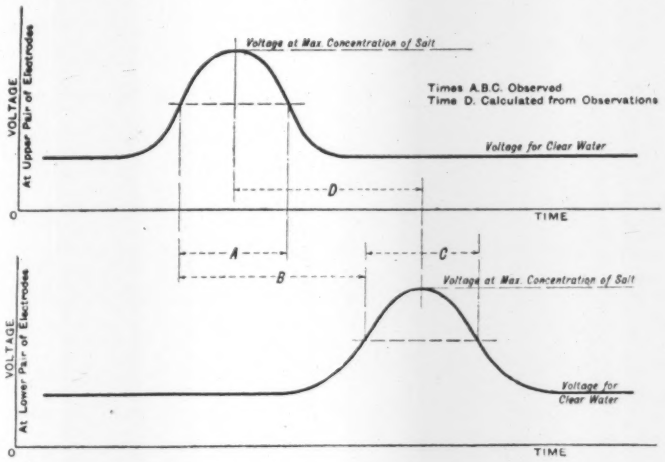

FIG. 3 VOLTAGE CURVES IN WATER-FLOW MEASUREMENT TEST

rapidly, toward a maximum. The maximum reading was obtained for an appreciable time, and then the voltmeter began to drop, at first rapidly and then more slowly, until it resumed its original reading for clean water. The rise of voltage indicated on the voltmeter was of the order of 30 volts, but depended to some extent on the velocity of flow.

If recording voltmeters had been available the type of diagram obtained would have been as shown in Fig. 3. The thick line on the upper diagram refers to the upper pair of electrodes, and that on the lower diagram to the lower pair of electrodes. The times measured were A, B, and C, and it was assumed that the mean time of passage of the salt between the two pairs of electrodes was $B - A/2 + C/2$, or that time indicated by D in the diagram.

The only point which it was not possible to check was the mean bore of the pipes, which had been already laid before it was decided to make these tests, and to have taken them up for measurement purposes would have been out of the question. There were, however, two pipes on the ground which were surplus and which were similar to those actually in the ground. The bore of these pipes was measured, the mean diameter of one of them being about 9.07 in. and that of the other about 8.91 in. It was assumed that the pipe was 9 in. bore, and it is improbable that the error introduced by so doing was more than 1 per cent.

Owing to the time occupied, only one reading was taken at the slowest speed of the water. The formula used for calculating the discharge of the weir was that given by A. A. Barnes.

It will be observed that the salt-method readings are of the same order of accuracy as the weir readings, assuming that the reservoir readings are correct. It will therefore appear that this salt method, if carefully carried out, is quite as accurate as any of the methods which are usually available for the measurement of flow in pipes, and it would seem to be a cheap and simple method where such measurements are required for testing the efficiency of water turbines or pumps or for other purposes. (Eric Crewdson in *The Engineer*, vol. 136, no. 3546, Dec. 14, 1923, pp. 635–636, 2 figs., *e*)

Comparative Tests of Experimental Draft Tubes

THIS paper gives the results of tests, made at the Alden Hydraulic Laboratory, on twelve model draft tubes, to determine the relative efficiencies of draft tubes of different types under the hydraulic conditions existing at a 120,000-hp. hydroelectric power plant now under construction.

The data and results are by no means considered final and comprehensive. They constitute a study of one specific problem, and are given to show that a great amount of research work, of which this is only a part, must be done before a complete set of empirical rules will be available for use in draft-tube design. It is hoped that the publication of this information will be the means of stimulating further and more valuable investigation of this important subject.

The accuracy and value of tests of this nature have often been questioned, sometimes because of a lack of knowledge of the conditions under which the tests were made; for this reason this paper gives a detailed description of the apparatus and methods used in making these tests. Precautions were taken for eliminating the usual sources of error, and it is believed that the relative values, and perhaps the absolute values, of efficiencies here shown are accurate to a very high degree.

The elbow or quarter-turn tube has for a number of years been a conventional type of design. Of late several new and highly efficient tubes designed on basic hydraulic principles had appeared, and the test data and theory on which they were based, together with the actual operating performance at a number of newly completed plants, indicated that the designers had valid claims for efficiencies much higher than could be obtained from tubes of the quarter-turn type. Complete tests of the various types, however, had not been made under identical conditions, and it was impossible for the prospective user to determine from available published data either the relative merits of the types of tubes offered or the type best suited to his needs. Some of the tests, furthermore, were made with the draft tube acting alone; and, although they were of great value to the draft-tube designer, the performance under this condition obviously did not apply when the tube was operating in connection with a water wheel.

Consequently, the Alabama Power Company authorized a series of tests on draft-tube models to be made at the Alden Hydraulic Laboratory of the Worcester Polytechnic Institute, at Worcester, Mass., for the purpose of obtaining a direct comparison of the efficiencies of various types of draft tubes and of determining their relative merits under conditions existing at the various power sites in which the company is interested.

It was decided that a comparison of definite value could be obtained only by testing the models under identical conditions, and only by observing the overall performance of the tubes and water-wheel models acting as a unit. The arrangement of the testing laboratory and instruments was made with these points constantly in mind.

For these tests there was available a model runner built by the Allis-Chalmers Manufacturing Co. and designed to be homologous with the 130-in. 24,000-hp. runners furnished by that company for Mitchell Dam, the installation where the draft tubes were to be used.

All the metal tubes were designed for identical hydraulic conditions, namely, those at Mitchell Dam, and therefore the results of the tests may not be used directly for other conditions if widely different; yet a direct comparison and performance may afford a basis for general conclusions that could be of value in designing tubes for other conditions.

The paper contains a list of the experimental draft tubes and a complete description of the plant and testing apparatus, as well as the methods of testing. This part is not suitable for abstracting.

The relative merits of the modern tubes are not easily determined from these tests. Changes in certain features of design were made in some of the tubes, and tests were made to determine their effect on performance. As these changes were not made throughout the entire set of tubes, a flat comparison of all tubes under identical conditions is not possible, although the effect of the changes on the tube itself may be noted.

As to results, the best in the entire series were obtained from a tube provided with a high central cone extending to the top of the tube. Another tube gave slightly better results with a high cone.

On the other hand, the low cones as tested with several tubes show no advantage over the flat plate, except to improve the characteristics of the individual gate-opening curves. These results would therefore indicate that a high central cone is a desirable feature in a tube of this kind.

As regards the effect of varying the throat discharge opening, curves obtained in the tests may be taken as possibly illustrating the best throat height for the particular tube tested, but do not afford a basis for a general conclusion regarding this feature.

The effect of extending downstream a horizontal discharge opening, of increasing the length of the vertical barrel, and of varying the discharge area were tested with various tubes. It was found that the extension is desirable, the increase of length of the vertical barrel produced a negligible effect, and that it is possible to make the taper of the discharge end too large to secure the best results.

An important feature of this investigation is the evidence obtained to the effect that fluctuations in draft-tube pressures vary in degree with the different designs, the fluctuations being least with the most efficient tubes. The vacuum charts in the original article indicate clearly the fluctuations that take place in a 1-mm. period. When the fluctuations were greatest, it was difficult to hold a steady load on the wheel.

The great difference in vacuum between the outer edge of the tube and the center shows that a piezometer in the customary place, that is, just below the runner on the outer wall, gives no reliable information as to the mean vacuum condition within the tube. In the case of one of the tubes, a piezometer on the outer edge recorded a positive pressure of about 6 in. of water, due to the centrifugal force of the whirling water, while the center piezometer showed a vacuum of $7\frac{1}{2}$ in. of mercury, or about 15 ft. of water. This high center vacuum just below the runner is no doubt the reason for the better results obtained with the high cones on two of the tubes.

The so-called "concentric" tubes were designed with the idea of providing the freest possible flow of water concentric with the vertical axis of the runner. In the "eccentric" tubes the design is modified, with the idea of better meeting structural conditions without unduly sacrificing the hydraulic advantages of the "concentric" tube. The comparative performance of these tubes gives a basis for determining to what extent the designing engineer may be justified in using the more complex designs, which are expensive and introduce serious structural problems, as compared with the simple tubes, which are more readily adapted to design and construction. In any case, the selection of the draft tube best suited for the type of runner adopted must still be considered as a specific problem in itself.

Although the tests discussed in this paper accomplished the particular purpose for which they were authorized, they are by no means comprehensive or final; and they are submitted with the hope that they will be supplemented by other tests made under different assumptions, from which may be deduced empirical rules that will be of value to the hydraulic engineer. (C. M. Allen, Mem. A.S.M.E., and I. A. Winter in *Proceedings of the American Society of Civil Engineers*, vol. 49, no. 9, November, 1923, pp. 1813–1845, 29 figs., *eA*)

INTERNAL-COMBUSTION ENGINEERING

A New Process of Steel Cylinder Construction

DESCRIPTION of a process of steel cylinder construction employing electric butt welding.

The cylinder head is formed by welding together two identical forgings. The principal feature of the design which is made possible by this construction lies in the fact that the valve port is forged as an integral part of the cylinder head and the parting line of the forging die is in the plane of the valve-port bosses.

The forgings are first machined on the bottom to allow them to be accurately located and also to give good electric contact with the copper welding dies. The welding is of the resistance type, hydraulic pressure being applied to force the two halves together.

It is claimed that the feature of making the cylinder head and valve ports integral has many advantages, the most important of these being elimination of the usual weld employed in attaching the two. This applies particularly to the four-valve design.

Tests conducted upon cylinders having no welded joint between the valve port and cylinder head indicated that the cooling of the valve seat is good and that the valve stem is more effectively cooled with this design of valve-guide bosses. (Glenn D. Angle, in charge of Aeroplane Engine Design, Engineering Division, Air Service, in *Aviation*, vol. 15, no. 27, Dec. 31, 1923, pp. 794–795, 3 figs., *d*)

Superchargers for Airplanes

PART of an article describing developments in the electrical industry during 1913, and prepared by the Publicity Committee of the General Electric Company.

A new turbine supercharger for airplanes was designed and built specially for extreme-altitude operation. It is rated to feed sea-level atmospheric pressure to the engine at a height of 35,000 ft., or about twice the rating of the one used in the previous American altitude-record flight.

The supercharger consists of a turbine compressor mounted just back of the propeller blades of the plane on the front end of the Liberty motor, and is operated from the red-hot exhaust gases from the airplane motor, which ordinarily go to waste. It weighs about 140 lb., which might be considered a handicap in altitude flying but for the fact that at 35,000 ft. its operation will increase the power of the Liberty motor by at least 280 hp., or about 2 hp. for each additional pound carried.

A supercharged plane at 1000 ft., making 126 m.p.h., can make about 150 miles at altitudes over 20,000 ft., whereas a plane without a supercharger can make 131 miles at 1000 ft. but only 70 m.p.h. at 20,000 ft. This shows that although there is a small loss in speed at low altitudes, there is a decided gain when flying at great heights.

The new supercharger has a rated speed of 33,000 r.p.m. but in tests it has been operated up to 41,000 r.p.m. or 683 turns of the compressor wheel a second, a speed probably greater than ever before attained in any commercial machine. (John Liston in *General Electric Review*, vol. 27, no. 1, Jan., 1924, pp. 11–12, *d*)

Crankcase-Oil Dilution

A SOMEWHAT general discussion of the subject, but containing data and presented in an interesting manner with a number of tables.

The author points out the generally known fact that the end point of average fuels for the past few years has gradually risen from 320 deg. fahr. in 1919 to 400 in 1918 and 438 in 1923. This high end point renders complete evaporation of the fuel a practical impossibility except in the case of engines operating at a constant high temperature. The appearance of fuel in the crankcase oil is not due to the condensation of vaporized fuel in the combustion chamber, but to raw fuel that has never been vaporized.

The author shows by a table the effect of various percentages of fuel dilution with relation to the Saybolt viscosities and pour points of some high-grade oils. From this table it will be seen that even 15 per cent of fuel has the effect of reducing the oil body by an amount equal to a 40-deg. rise in temperature above 104 deg. fahr., and a 25 per cent fuel content thins the body as much as a 70-deg. increase in temperature of fresh oil above 140 deg. fahr.

The author discusses the subject of emulsification of crankcase oil, about which less is generally known than about straight dilution. He shows that if the oil is fresh and properly refined, water will not remain in permanent suspension, but as the oil becomes contaminated with matter due to metallic wear, road dirt, free carbon, and acidulated moisture resulting from the combustion of fuels with sulphur content, its ability to separate from the water is lessened. To prove this he gives a table showing the results obtained by using an exceptionally well cleaned-up turbine oil having a demulsibility value of 500 as against an average value of somewhat over 300 for high-grade automobile oils. The addition of a small quantity of carbon and carbonaceous matter has reduced the demulsibility to zero. The relatively high demulsibility reading on the fresh oil was practically eliminated after the oil was in the crankcase 5 min. It was, however, not only restored but bettered as a result of filtering oil through paper. (E. F. Hallock, Manager, Manufacturers Service Division, Vacuum Oil Co., Rochester, N. Y., in the *Journal of the Society of Automotive Engineers*, vol. 14, no. 1, Jan., 1924, pp. 57–62, *p*)

The World's Largest Diesel

CONTINUATION of the story of constructing a marine engine which developed over 17,000 shaft hp., the first installment of which was printed in the February issue of this journal, pp. 96–97. The type of injection adopted was somewhat tangential and not disturbed by the piston rod. The new engine was equipped on each end with only two combustion pockets. The cylinder was built up of three parts, an upper and a lower one, both of which were left to expand axially with perfect freedom, and a center which itself was made up of two pieces and contained an exhaust. All three parts were fitted gastight and bolted together. Very careful attention was given to the cooling of the cylinder walls, which for this purpose were made especially thin. The effect of cooling water was increased by fitting a jacket around the liner having helical heads which forced the water to shoot around the liner with great velocity.

The problem of the heat stresses was considered of such vital importance that an investigation was undertaken to measure the temperatures in the liner directly by a number of thermocouples, and the original article gives data as to the method used and some of the results obtained.

An effort was at first made to keep by artificial means the average temperature of the cycle as low as possible, and the best results were obtained by blowing water into the cylinder through the fuel valves. All these attempts were, however, finally abandoned, because the combustion became irregular and a loss of power was observed. It became evident that good results could only be obtained by improving the combustion, and in this connection it was found that the production of good fuel injection was of paramount importance.

The article proceeds to a discussion of experiments undertaken with the object of discovering the influence on the strength of the cylinder of quickly repeated starting and stopping maneuvers which induced, among other things, acute temperate stresses. These were met by the use around the valve chambers of a water-cooled shield ring, the employment of which made it necessary to redesign the upper cylinder part. (Second part of article by Frederick Englert, Chief Engineer, Nuremburg plant of the Augsburg and Nuremberg Machine Works, in *Motorship*, vol. 9, no. 1, Jan., 1924, pp. 40–41, 7 figs., *de*)

MACHINE DESIGN (See Special Machinery)

MACHINE PARTS

The Bennington Speed Reducer

THIS speed reducer is of the planetary type with gears mounted in a cage. The low-speed shaft is connected to the cage by means of a flexible connection which is mounted in the end flange of the planetary gear cage substantially as follows: In the flange of the cage there is an annular flange or ring inside of which are circumferentially mounted rockers each having a tooth which projects inward to engage with the toothed sector or spider which is keyed and shrunk on the low-speed shaft.

In the annular flange or ring are mounted spring members having plungers extending inward and engaging on each end of the rockers (there being one on each side). As power is applied to rotate the high-speed pinion these plungers come into operation so that the cage starts to revolve. The slow-speed shaft remains fixed until the rotation of the cage causes the teeth of the toothed sector which is fixed to the shaft to engage with the teeth of the rockers, thereby rocking the rocker and compressing the spring plunger on either side of the rocker, depending on the direction of rotation, until the rocker bottoms on the inside of the annular flange, when the low-speed shaft picks up the load. Because of the bottoming of the rocker the contact is positive and the springs do not take up alternating loads.

Because of the employment of spring plungers it is claimed that certain advantages are attained. While the springs in the plungers are being compressed, i.e., at starting, the only load the motor has to assume is sufficient power to compress the springs, which means that during that period the prime mover starts with practically no load and picks up the load gradually, while the planetary gears make a quarter-turn. Also, while springs are being compressed the teeth of the gears are held in close contact, thereby eliminating vibration and backlash.

The gear operates in either direction and may be used either as a step-up or a step-down. Gears of this type are said to be made in ratios up to 25 to 1 in single reductions and up to 200 to 1 in double and triple reductions, and in any horsepower up to and including 500 hp. ("Tyler Patents," Bennington Scale Mfg. Co., Commercial Publication, pp. 1–26, illustr., *d*)

MECHANICS

Polar Diagrams for Riveted Connections

THE diagrams forming Fig. 4 illustrate a method of determining by means of a polar diagram the forces acting on the rivets of a connection subjected to an eccentric force. In the method outlined, the construction is arranged about a center point, or the intersection of two axes at right angles to one another, the principal axis being drawn parallel to the line of action of the eccentric force applied to the connection. The direction of the moment force for each rivet is first investigated from a sketch of the connection, on which it may be drawn normal to a line passing through the center of the rivet and the center of gravity of the rivet group, and acting in the direction in which the eccentric force would tend to rotate the connection were it free to revolve about the geometric center if the rivet group, as in Fig. 4.

The magnitude of the moment force for each rivet may be obtained from the formula Ba_1/I_p, where B is the twisting moment of the connection, or the load multiplied by the eccentric arm, a_1 the arm of the individual rivet, and I_p the polar moment of inertia of the rivet group.

The magnitude of the direct force for each rivet is the load divided by the number of rivets forming the rivet group.

The force diagram is constructed by transferring the moment force vectors, in magnitude and direction, from the sketch and arranging them as radial vectors about the origin, or center point, of the diagram, as in (*b*), Fig. 4.

Vectors representing the direct forces are drawn, extending from the extremes of the moment vectors and parallel with the principal axis, as in (*c*), Fig. 4.

The effective force resisted by each rivet is finally represented by a line joining the extremity of the direct force vector with the center point of the diagram. The result is a polar diagram, in which the resultant forces radiate from the center as shown at (*d*), Fig. 4. The direction of the eccentric force is indicated by an arrow marked F.

In (*e*) to (*h*), Fig. 4, are given diagrams for eccentric forces acting in various directions. (*e*) illustrates the eccentric force acting vertically downward; (*f*) the eccentric force acting horizontally; (*g*) the case in which the eccentric force is collinear with the moment force of rivet No. 1; (*h*) represents a five-rivet connection; (*i*) illustrates the resultant forces on the rivets of a connection—such as a gusset-plate connection for diagonal bracing—when the eccentric force acts consecutively in three different directions, F_1, F_2, and F_3. It will be observed that the maximum force occurs when the moment force for any rivet acts parallel with the eccentric force. (J. B. Clarke in *The Engineer*, vol. 136, no. 3546, Dec. 14, 1923, p. 639, illustrated, *t*)

MOTOR-CAR ENGINEERING (See Internal-Combustion Engineering)

PIPE

Commercial Efficiency of Single and Graded Steam-Pipe Covering

RESULTS of tests on heat-insulating materials (magnesia, air cell, asbestocel, carocel, nonpareil, sponge felt, and multiply types) recently conducted at the State College of Washington and reported in Engineering Bulletin No. 12 by H. J. Dana. Their primary object was to provide information as to use of commercial steam-pipe coverings.

The article describes the method of testing and presents some of the data of these tests.

The most interesting are those shown in Fig. 5, indicating the values of the conductivity factor K for the various materials. Another set of curves in the original article shows the economic value

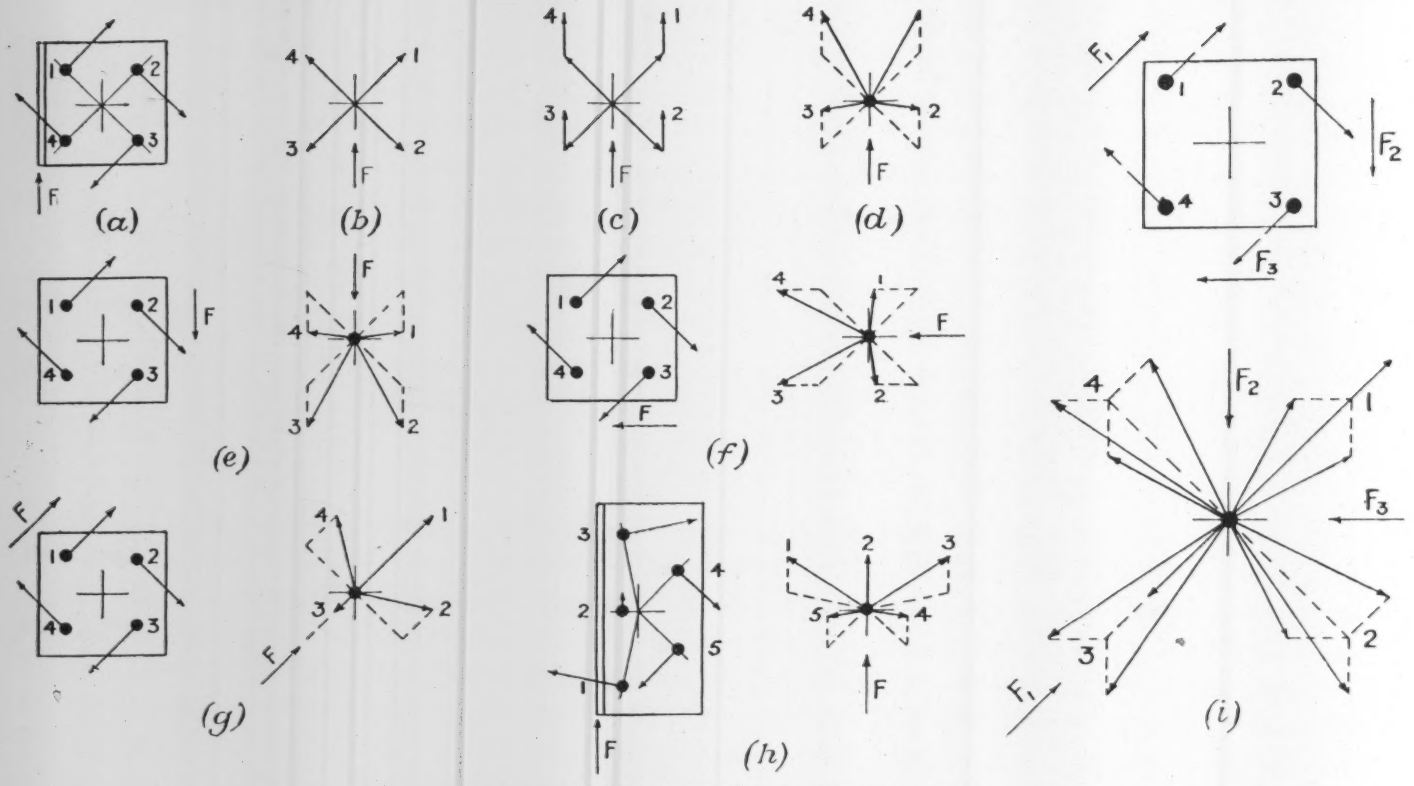

FIG. 4 POLAR DIAGRAMS FOR RIVETED CONNECTIONS

of the second thickness of covering on 5-in. steam pipe, and indicates the savings in dollars per lineal foot per year due to adding either of three different coverings over a covering of 1-in. magnesia alrady in place on a 5-in. pipe. In addition, it also shows the annual cost of single-thickness coverings large enough to go over the coverings already in place. This annual cost is computed on the basis of the list price, at discounts up to 60 per cent off, plus 10 per cent of list price for erecting; assuming 6 per cent interest on total first cost and 5 per cent of total first cost for upkeep, etc. The basis for computing the sinking-fund annuity is 6 per cent.

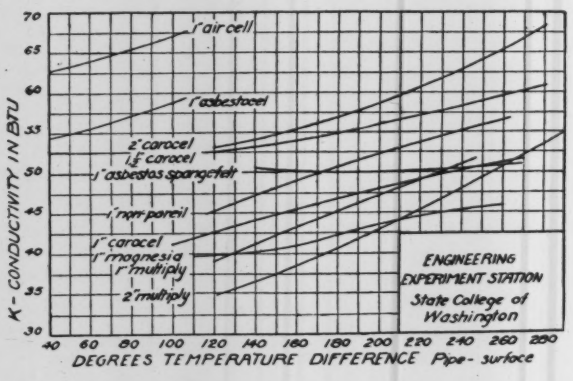

FIG. 5 VALUES OF CONDUCTIVITY *K* FOR SAMPLE COVERINGS

As an illustration of the use of the chart, a given installation of 5-in. pipe is carrying 125 lb. of steam and is covered with 1-in. magnesia. Room temperature is 80 deg. fahr. Examples are given where the investment is to be returned in 14, 20, and 30 years. Market prices of covering are assumed to be as shown in a table given in the article.

In the three cases cited the greatest total annual saving would accrue from using magnesia. However, aircell, the most inexpensive covering of the three types considered, will show the greatest per cent return on the annual cost.

The original article gives market prices of different coverings per lineal foot. The use of tin-jacketed coverings is also briefly discussed, and a sample calculation of heat loss from a domestic water-heating system is given, showing the savings that may be obtained by the various types of pipe covering. (*The Heating and Ventilating Magazine*, vol. 21, no. 1, Jan., 1924, pp. 48–52, 6 figs., *ep*)

RAILROADS (See Special Machinery)

SPECIAL MACHINERY

New Tube Cutting-Off Machine

DESCRIPTION of a new device built by the Treadwell Engineering Co., of Easton, Pa., and installed in the pipe-finishing department of the LaBelle Iron Works, Steubenville, Ohio. The machine was built under a guarantee that it would cut off both ends of 8-in. standard pipe at the rate of 60 pipes an hour, but actual tests are said to have shown it to be capable of exceeding this performance by a considerable margin.

Two driving heads are provided. These are built in halves and open and close to receive and discharge the tube. Each half of the driving head carries half of the main driving gear and both of the half-units are so mounted that when in a closed position they form one solid member. The driving heads are direct-connected through a telescope shaft to the main drive, while individual motors are provided for a rapid traverse of the heads to suit any variation in the length of the tube.

Each end of the machine is equipped with two cutting-off tools which are driven through a friction clutch from the main driving shaft, changes in feed being obtained through the medium of a nest of change gears.

The method of mounting the heads necessitated the stopping of the unit always in the same position, the vertical split being preferable because of the method adopted of handling the pipe in and out of the machine. To meet this requirement a control was developed which stops the machine at the same point regardless of the motor speed or of the position of the driving head at the time the operator turns the control lever.

The original article describes and illustrates the details of the machine, among others the automatic feed and the system of interlocked controls. (Designs New Cutting-Off Machine, by E. W. Mikaelson, Chief Engineer, Treadwell Engineering Co., Easton, Pa. *Iron Trade Review*, vol. 74, no. 2, Jan. 10, 1924, pp. 173–176, 6 figs., *d*)

The Lenz Hydraulic Transmission System

DESCRIPTION of a new type of compound reduction and reversing gear for application to marine work, said to have been recently developed by an Austrian firm. The device consists of a pump and motor incorporated in one casing and having their shafts at right angles. The vanes of the pump and motor are free to move radially in their respective rotors (Fig. 6), and are constrained to move in their correct path during rotation by rollers attached to their ends and working in grooves cut in the end casings.

In order to provide a wide range of propeller speed with constant engine speed the pump is divided into two sections, one section having twice the width of the other, and by a suitable arrangement of control valves either section separately or both together may be used. This gives three particular shaft speeds for one particular engine speed, and intermediate shaft speeds can be obtained at the same engine speed by passing a portion of the oil from the discharge side of the pump to the suction side.

Reversing is effected by the action of the control valves which,

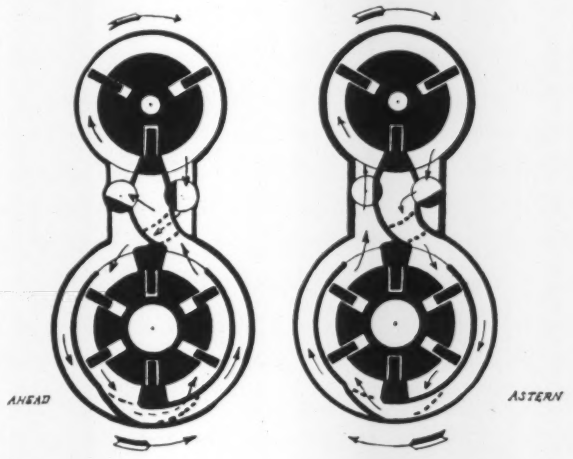

FIG. 6 LENZ HYDRAULIC TRANSMISSION SYSTEM

when suitably set, reverse the flow of oil to the motor, the action being readily followed from the diagram.

Relief valves are fitted wherever an accumulation of pressure is likely to occur, and arrangements are made for passing some of the oil through a cooler as a certain amount of heat is developed by friction and churning. (*Motorship*, vol. 9, no. 1, Jan., 1924, p. 21, *d*)

A Flame-Proof Gasoline-Driven Locomotive for Mines

DESCRIPTION of a Belgian locomotive for mines that has been approved by the Belgian Government Inspector of Mines.

To prevent the communication of flame to the external atmosphere special devices are fitted to the inlet and exhaust pipes. The former is provided with a number of thin circular plates spaced $^1/_2$ mm. apart; these plates provide a large cooling surface, and, in conjunction with the small space between them, extinguish any flame caused by backfiring resulting either from leakage or the inlet valve not closing properly. The silencer is provided with nickel-steel balls resting on an iron grid. These balls are kept cool by the circulating water from the exhaust-valve water jacket and insure the hot gases coming in close contact with the water, which extinguishes any flames which reach that point. After passing through this device the exhaust gases pass through one similar to that fitted on the inlet pipe, which provides an additional security.

The locomotive is built in two types, one of 6 to 7 hp. and the other of 12 to 14 hp., capable of traveling at a speed of 4.35 m.p.h. with loads of 14 and 28 tons, respectively. (*The Iron and Coal Trades Review*, vol. 108, no. 2914, Jan. 4, 1924, p. 25, 1 fig., *d*)

Balancing Large Rotating Apparatus

DESCRIPTION of a balancing machine which can be used for very large rotors, one type illustrated in the article being rated for rotors weighing up to 300,000 lb.

The general principle involved in this machine provides for placing the rotor to be balanced in bearings mounted in pendulum supports with springs at the side which permit small lateral oscillations. The rotor is then driven at a speed identical with the natural period of vibration corresponding to the weight of the rotor, its bearings and the scale of the springs thus allowing successive synchronous impulses of the centrifugal forces of the unbalanced masses to give the system a large and measurable amplitude of vibration. This general principle is old and was described by Stodola in connection with steam-turbine rotors many years ago.

The machine consists essentially of two pedestals mounted on rigid bed rails together with a driving motor and special magnetic clutch for rotating the rotor, as well as a complete lubricating system. The rotor is supported by self-aligning pad bearings, which are in turn supported by an inverted pendulum. The lower half of the pendulum is stayed transversely by flexible struts and the upper end is supported on both sides by springs, which give the system the desired frequency. Geared stop screws operated by a handwheel allowed each pendulum to be locked in a position of alignment with a driving motor and clutch.

Two bearing shoes are used with each pedestal. Each is pivoted on a button support and becomes self-aligning after the manner of the well-known Kingsbury thrust-bearing segment. Different sizes of shoes are used with different journal sizes, the bearing support being adjustable.

By this construction bearing pressures as high as 1000 lb. per sq. in. of actual area may be employed, if necessary, but 750 lb. per sq. in. is commonly practiced. This is easily feasible with the rotor revolving with ordinary lubrication and so maintaining the oil film. Provision is necessary, however, to establish the oil film before the rotor is revolved or the bearings might wipe with the first fraction of revolution. This is accomplished by admitting high-pressure oil to the four corners of the bearing pads in a special manner which raises the rotor an approximately equal distance from the whole surface of the pad, and so establishes an oil film before the rotor is moved.

The original article describes the method of balancing, which appears to be comparatively simple. As regards the accuracy of the balance obtained, it is stated that the maximum permissible amount of residual unbalance at the balancing ring at each end of the spindle is never allowed to exceed one inch-ounce per thousand pounds of rotor weight. For instance, the residual unbalance at each end of a turbine spindle which weighs 35,000 lb. is not allowed to exceed 1.9 oz. measured on the balancing ring, which has a radius of 18 in. On a spindle weighing 85,000 lb., with a balancing-ring radius of 20.5 in., the maximum permissible error in balancing as measured on the balancing ring is 4.15 oz. One of the smallest of the combination impulse reaction rotors weighs 860 lb. The maximum permissible error, as measured on its balancing ring of $6^3/_{16}$ in. radius, is 0.14 oz. The design of the balancing machines, however, is of such character that increments of one-fifth of the specified limits will give distinct indications.

The largest piece that has been balanced so far was a stabilizer rotor weighing 230,000 lb. with a balancing-ring radius of 64 in. It was desired to secure superlative balance of this rotor and the author and his associates were able to secure response in the balancing machine to a weight at the balancing-ring radius of as small as $^1/_2$ oz.

This corresponds to a residual unbalance of that amount. The result was such nearly perfect balance that when the stabilizer was operated at full speed, one could not have told that the machine was operating had it not been for the windage noise of the driving motor.

With this stabilizer rotor the sensitiveness of the balancing machine was found to be 0.008 in. change in pendulum amplitude for a change in weight of 1 oz. at the 64-in. radius. This was found true up to 3 oz. change in weight; that is, with 0.0005 in. amplitude on one end, the addition of 3 oz. increased the amplitude to 0.024 in.

There are, however, some other factors which will affect the smooth operation of the machine besides untrue journals and other similar things previously referred to, of which the most important is static unbalance. (L. E. Fletcher, of the Turbine Engineering Dept., Westinghouse Elec. & Mfg. Co., in *Electric Journal*, vol. 21, no. 1, Jan., 1924, pp. 5–10, 5 figs., *d*)

A New Electrical Telemeter

DEVELOPMENT work has been in progress for several years at the Bureau of Standards on an electrical telemetric device suitable for the measurement of strains, forces, displacements, and accelerations, with the view of making an instrument for remote reading and remote recording, and at the same time adapted to the measurement of quantities that are rapidly varying in value. Instruments capable of accomplishing these purposes would have numerous advantages over those for similar purposes now in use, since the latter are suitable only for measuring values that are relatively steady, and instead of being remote reading or recording must be read at the point of measurement. Satisfactory progress has been made and instruments developed that have sufficient accuracy and stability for many kinds of engineering measurements.

For their operation these new instruments depend upon the pressure-resistance characteristic or the corresponding displacement-resistance characteristic of a stack of carbon plates. Previous attempts to make use of these characteristics in making engineering measurements have met with little success on account of erratic changes of resistance in the stacks, hysteresis effects, and inability to obtain a linear relationship between resistance and pressure or displacement. The first of these has been overcome by maintaining the stack always under considerable pressure and confining changes of pressure and displacement within comparatively narrow limits to prevent any lateral shifting of the carbon contacts. Care is also taken to apply pressure changes axially to the stack to prevent bending or twisting.

Hysteresis effects have been made negligible by the use of a mounting without mechanical joints, so that if a given pressure or displacement is approached from either a higher or lower value the result is practically the same, whereas with mechanically jointed mounting frames there is a wide discrepancy, in some cases amounting to as much as 50 per cent.

A linear characteristic is obtained by incorporating in each instrument two stacks of plates in such a way that the force or displacement under measurement causes the resistance of one stack to increase and the other to decrease. By experiment it has been found that the cumulative change of resistance of the pair of stacks gives substantially a straight-line characteristic to the instrument.

In order to utilize the change of resistance of the stacks they are made two of the arms of a Wheatstone bridge, with fixed resistances as the other two arms. The bridging instrument may be a milliammeter, galvanometer, or oscillograph element, and the deflections may be read directly or recorded photographically.

Practical applications so far made consist of the following:

1 Measurement of loads in airplane stay cables during flight.
2 Measurement of strains in airship girders and bridge members during construction tests.
3 Tests of bridge members subjected to live loading.
4 Tests of airship girders and bridge members in the laboratory.
5 Measurement of pull on pressure arm of a dynamometer.
6 Measurement of pressures ranging from a few millimeters of mercury to 40,000 lb. per sq. in.

The use of these instruments results not only in a great saving of time and effort where a great many readings are to be made, but also enables the making of several classes of measurements not hitherto obtainable in their true proportions. (Burton McColum and O. S. Peters. Abstract of *Technologic Paper of the Bureau of Standards*, no. 247, *d*)

SPECIAL PROCESSES (See Engineering Materials, Internal-Combustion Engineering)

Wet-Process Enamels for Cast Iron

WET-PROCESS enameling of cast iron is becoming of importance because of its application to the enameling of stove parts, sanitary fittings, and hardware. This paper is a report of an extended investigation of wet-process enamels for cast iron, both with and without the use of ground coat. Compositions used in dry-process enameling have served as a basis for the work. The effect of varying methods for preparation of the frits, mill additions, and relation of composition of the enamel to such properties as adherence, texture, and opacity have been carefully studied.

Ground Coats. Sintering of most ground-coat frits has been found desirable in order to develop best adherence of the enamels to the casting. Clay gave best results as a mill addition for the ground coats and flint and feldspar were found to be less satisfactory. Excessive additions of clay or flint produced flaking of the ground coat, while feldspar tended to develop blistering. About 15 per cent of clay or 10 per cent each of clay and flint are recommended as a mill addition for the ground coat.

Excessive additions of any one flux were not desirable and best results were obtained when sodium, lead, and boric oxides were combined in more or less definite proportions. Sodium oxide in excess of about 10 per cent gave rise to blistering. Boric oxide increased the firing range of the ground coat and was preferable to lead oxide on this account, although it tended to promote crawling of ground coats high in boric oxide if they were applied somewhat heavily. Details of the best ground coats developed are given in the original publication.

Cover Enamels. These were smelted by the usual method for enamels. The mill additions consisted of 5 per cent of clay, 8 per cent of tin oxide, and 45 per cent of water, all based on the weight of the dry frit.

For best results the cover enamel must be adapted to the ground coat in refractoriness. Boric oxide increased the firing range of the enamel, but tended to promote crawling, although this was less pronounced in the case of the more fusible composition. Boric oxide improved the capacity when substituted for such fluxes as sodium and lead oxide. Cryolite increased opacity, but additions above 10 per cent tended to promote crawling. The compositions described in the original article gave satisfactory results.

Single-Coat Colored Enamels. These enamels are smelted in the same manner as used in the preparation of the white cover enamels. The effects of the various ingredients are very similar to those noted in the case of white cover enamels. Suitable mill additions consist of 4 per cent of clay, 50 per cent of water, and the necessary amounts of color oxide to give the colors desired. Enamels of the feldspar type are apparently more satisfactory than those containing flint as the sole refractory. The compositions listed in the original article are typical of those which have given satisfactory results.

Single-Coat White Enamels. In the production of single-coat white enamels it is necessary to develop maximum opacity in the frit, since the addition of more than three or four per cent of tin oxide in the mill batch causes blisterings of the enamel when applied to the iron. Suitable mill additions for enamels of this type are as follows: Clay, 4 per cent; tin oxide, 4 per cent; and water, 45 per cent.

In no case were the results with the single-coat white enamels as satisfactory as those obtained with a white enamel applied over a ground coat, particularly in regard to the opacity. Enamels giving the most satisfactory results are listed in the original paper. (R. R. Danielson and H. P. Reinecker in *Technologic Paper of the Bureau of Standards*, no. 246, *d*)

TESTING AND MEASUREMENT (See Hydraulics)

TRANSPORTATION (See Special Machinery)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

An interesting device described by C. A. Hoxie in the *Journal* of The American Institute of Electrical Engineers (vol. 42, 1923, pp. 520–535) is the pallo-photophone, which is an instrument for registration and reproduction of sound waves. It utilizes the photo electrical cell to change light energy into electric current, the cell being a two-electrode device of the kenotron type. Its cathode is, however, cold and consists of a layer of metallic potassium on the inner surface of the glass. Potassium is used because it has the property of emitting electrons when light falls on it. The emission is instantaneous and the number of electrons emitted is exactly proportional to the intensity of the light.

Correspondence

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The Elasticity of Pipe Bends

TO THE EDITOR:

I read with interest the article by Messrs. Crocker and Sanford on the design of pipe bends in the March, 1923, issue of MECHANICAL ENGINEERING. This subject is of great importance in the oil-refining industry, and especially so in cracking plants where temperatures of from 750 to 1000 deg. fahr. may be employed at pressures ranging from 100 lb. to over 1000 lb. per sq. in. Since a failure of a pipe or joint under these conditions is almost certain to cause a dangerous fire, it is of prime importance that expansion be fully considered in designing.

In using the charts which accompanied the article I found them rather unwieldy for smaller sizes of piping with a large expansion

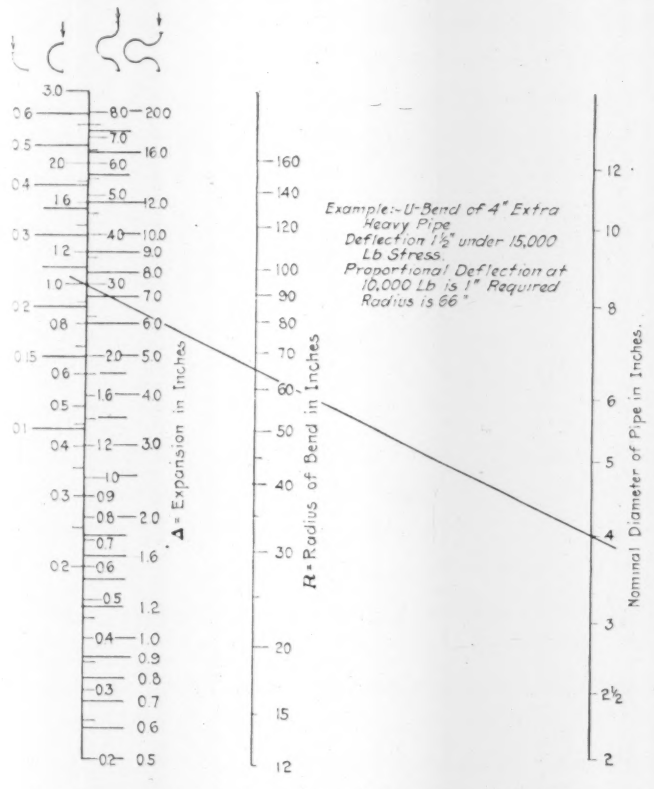
Δ = Expansion in Inches
R = Radius of Bend in Inches
Nominal Diameter of Pipe in Inches.
Example:- U-Bend of 4" Extra Heavy Pipe
Deflection 1½" under 15,000 Lb Stress.
Proportional Deflection at 10,000 Lb is 1" Required Radius is 66"

FIG. 1 EXPANSION BENDS. ALLOWABLE EXPANSION FOR UNIT STRESS OF 10,000 LB. PER SQ. IN.

(This chart gives the expansion cared for by various types of bends at a unit stress of 10,000 lb. per sq. in. At any other stress the expansion found should be multiplied by $S/10{,}000$. Formula used: $S = CD\Delta E/R^2$, where S = unit stress, D = outside diameter, Δ = expansion, E = modulus of elasticity, R = radius of bend, and C = constant depending on type and having the following values: Quarter-bend, 1.404; plain U-bend, 0.318; expansion U-bend, 0.106; double-offset expansion U-bend, 0.0427.)

and therefore designed the two accompanying alignment charts, Figs. 1 and 2, to take care of the formulas given in the original article. I have found that the use of these two charts greatly simplifies the process of designing a pipe bend and the necessary anchorage.

To find the load on an anchor, both charts should be used in conjunction so that the allowable unit stress in the pipe will not exceed safe limits.

It will be noticed upon comparing the results given by these charts against other design tables that quarter-bends in particular have little expansion value, and that the unit stress in the pipe wall must be very high for the expansion value allowed in some cases. The original article cites the results of tests to substantiate the formulas and it is noted that in some cases the flexibility is greater than that figured, on account of the waves formed in the pipe wall on the inner side of the bend. Quoting from the original article: "Attention is called to the fact that in no case did the tests show a bend to be less flexible than the formulas would indicate, so if the formulas and design graphs presented in the paper are used in practice, the designer will always be on the safe side. His

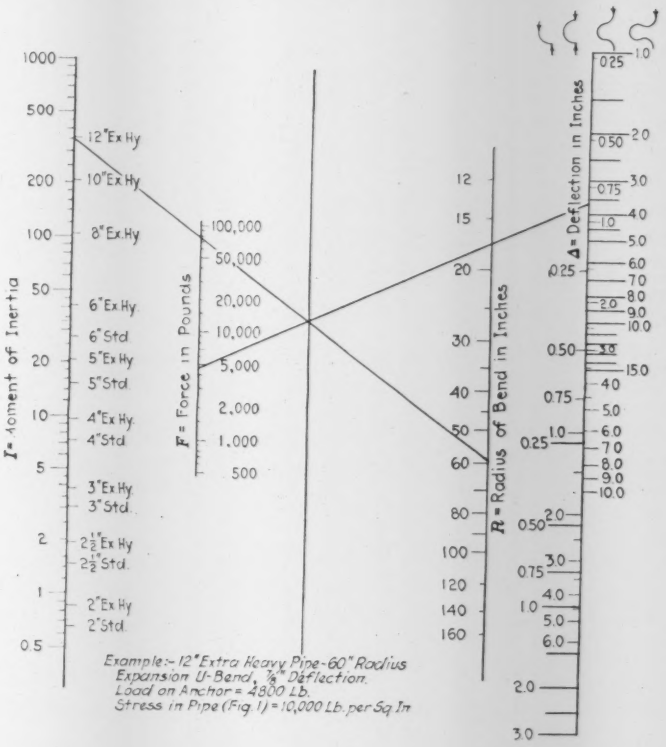

FIG. 2 EXPANSION BENDS. FORCE AGAINST ANCHOR FOR VAR TYPES OF BENDS

(This chart gives the force against an anchor for any deflection of various types of pipe bends. For other sizes of pipe than those given, find moment of inertia $I = 0.393\ t(D^3 + t^2D)$, where D = mean diameter. Formula used: $\Delta = FR^2/EI$.)

bends may or may not be more flexible than his calculations would indicate, but he need not fear that forces or stresses in excess of his calculated values will exist."

As the two alignment charts presented are based on the same formulas, the same statement holds true. An example is given on each of the charts which will serve as an explanation of the way they are to be used.

DONALD J. BERGMAN.

Chicago, Ill.

[Mr. Bergman's letter and charts were placed before the authors of the paper in question, and the following communication has been received from Mr. Crocker.—EDITOR.]

TO THE EDITOR:

I am glad to have this opportunity to comment on Mr. Bergman's charts. Mr. Sanford and I have checked these over and agree that they furnish another useful way to present the formulas of our paper in graphic form. As Mr. Bergman says, they have a distinct advantage over the displacement versus force charts of the original paper for dealing with small pipe sizes. The addition of

the moment-of-inertia alignment chart should prove extremely useful to persons having occasion to solve our formulas involving I for cases not covered by the graphs, through saving them the trouble of calculating this quantity for the size of pipe in question. However, the authors are of the belief that the graphs given in their paper have on the whole a more direct application than those of the alignment-chart variety. For one thing, their charts give stress directly without the use of a conversion factor based on a stress of 10,000 lb. per sq. in.

It should be noted that the exact mathematical formula for the moment of inertia of a cross-section through a pipe is

$$I = \frac{\pi(d_1^4 - d_2^4)}{64}$$

where I = moment of inertia about an axis passing through the center of section and lying in its plane, d_1 = outside diameter of pipe, and d_2 = inside diameter of pipe. Using the symbols of Mr. Bergman's formula, placing $d_1 = D + t$ and $d_2 = D - t$ and substituting in above formula and solving, we get

$$I = 0.3927\, t(D^3 + Dt^2)$$

which does not agree exactly with Mr. Bergman's formula.

SABIN CROCKER.

Detroit, Mich.

The Present Status and Future Problems of the Art of Cutting Metals

TO THE EDITOR:

I regret that I was unable to attend the session of the Annual Meeting at which the Progress Report on the Present Status and Future Problems of the Art of Cutting Metals was presented, and am therefore now contributing my views on the subject in writing.

The report gives an excellent résumé of work already accomplished and in a desirably summarized form. It, fails however, to map out the work immediately ahead, much to my disappointment. I have further learned that there was no discussion at the meeting in which a substantially clear-cut program for immediate action was proposed. Because of this I am taking the liberty to outline my views on the subject and to suggest a definite line of attack for the next one or two years.

Frederick W. Taylor elevated the cutting of metal from a trade to an art. From fear of being misunderstood I must add that no one could possibly appreciate more the magnitude of the work he did and feel greater admiration for its pioneering nature than I do. However, I venture to say that his work has been misinterpreted and, in some respects, too slavishly followed: in thought more than in action. I believe that if Taylor had lived, he would have pointed this out already. The time seems to be ripe for viewing the entire subject from an a priori basis.

The thought in mind is best approached by allegory: Taylor discovered the existence of a vast continent, the existence of which was unsuspected. He made notes on various mountains, rivers, and valleys, but did not have time to take latitudes or longitudes. Subsequent investigators have made hurried excursions into this continent and have done exactly the same thing. The value of all this work is seriously impaired, because the location of everything is unknown. It would seem that systematic, elementary work should be done first to give the skeleton outline and build the framework into which all later observations can be fitted and tied together so as to form a coherent whole.

To come back to the Art of Cutting Metals, investigators have worked from the surface downward rather than from the bottom upward. Taylor deliberately entitled his researches "On the Art of Cutting Metals," and rightly so.

As a first move, which would probably have considerable psychological advantage, I would suggest that the title be changed to "On the Science of Cutting Metals." This would help to inculcate a new point of view.

The subject has one very evident and definite fundamental plane of cleavage into the two divisions outlined below. The connection between them is comparatively slight and could for the next two or three years, even with intensive work in this field, be almost ignored.

1 A STUDY OF THE ACTION IN CUTTING METALS WITH TOOLS OF KNOWN GEOMETRICAL SHAPE AND INFINITELY SHARP OR OF A SCIENTIFICALLY KNOWN DEGREE OF BLUNTNESS. It appears axiomatic that all forces involved would be exactly the same if two tools were used of the same geometrical definition, even though one tool be made of cast iron and the other of the best steel procurable: in this of course we assume that the cast iron would stand up, which it would not. The thought here intended is that the quality of the steel in this tool can be completely forgotten and whatever steps are necessary must be taken to keep constant the geometrical definition.

2 THE PERMANENCE OF A GIVEN GEOMETRICAL FORM OF TOOL FOR DIFFERENT KINDS OF STEEL, DIFFERENT CONDITIONS OF HARDENING AND FOR DIFFERENT KINDS OF USAGE.

If research in this subject be undertaken, truly building up from the bottom, it will be several years before fruits are obtained of commercial value. In the meantime conditions will arise such that commercial interests will require information regarding specific types of action and will proceed by the method of "boring from above."

The better plan appears to be for a national society to conserve all its energy to control the fundamental work and so bring nearer the time when this will burst through the surface and deal with specific commercial situations. The surface work could well be left decentralized. Coördination of this, on a satisfactory basis, may be said to be of doubtful value in the absence of the underlying structure.

From a scientific standpoint, investigation in (1) is of much greater fundamental importance than that in (2), as the latter must be built on the former to a considerable extent. The greater the amount of energy absorbed in taking a given chip the greater the amount of heat that will be generated, and this is the prime factor in influencing the permanency or otherwise of the geometrical shape.

Three topics in division (1) are:

a Express energy required to remove unit volume of metal as a function of rake.

b Express energy required to remove unit volume of metal as a function of clearance.

c Express energy required to remove unit volume of metal as a function of skew.

They presuppose a material of constant quality, and preferably the two extremes should be taken, namely, exceedingly ductile and exceedingly brittle material. The first topic is of the greatest importance. The answer to the second is probably known already. The difference between the first and the third would be due to the side movement, causing friction. In investigating these topics straight-line motion should be employed. By all means let us reject the incidental complexity of circular motion or anything removed from the simplest possible terms. Furthermore, it is certainly possible, although how difficult cannot be foreseen, to find the solution to (*a*) on a *rational* basis. That is, the energy required to remove a unit volume of metal would be expressed in terms of known physical attributes of the material being cut. If this were accomplished we should have an analytical tool of the first magnitude, and such a result would be well worth one or two years' work and a considerable expenditure of funds. When put on a rational as opposed to an empirical basis, it will doubtless furnish an analytical instrument useful in studying all types of action in metal cutting and will enable us to probe intelligently into the subject instead of groping in the dark.

To enlarge further on the major problem mentioned in the last paragraph, it will be noted that this would involve the establishment of a mechanism of failure of material under compound stress. This in itself is a problem of a very high order, entirely apart from its application to the cutting of metal, and incidentally one that would naturally attract the support of the American Society of Civil Engineers, as they are vitally interested in the problem from a strength-and-resistence-of-materials standpoint.

It is my opinion that to lay out a program in the science of cutting metals beyond the three topics outlined above, would be to proceed

blindly. The solution, or partial solution, of the problems they involve would shed such illumination on other matters as to cause a different interpretation of results.

A very elaborate detailed study would doubtless have to be made of the actual cutting in order to arrive at the results desired. The photoelastic method should certainly be fully considered, as it is quite probable that it would at least throw some light on the detailed action at work. However, it is certain that many thousands of carefully performed experiments will be necessary with extreme and representative types of material before an intelligent study can be made, and even then creative, analytical thinking of a very high order will be necessary to accomplish the desired end.

If this one topic could be investigated, say, at three different institutions simultaneously, it would be well worth while, for the problem is such that the collaboration of our best technical talent will be needed before its solution is reached. I look upon this problem as the biggest single one of the whole subject, and, believing that its solution would put the entire situation in a new light, would therefore prefer to see all possible energy concentrated on it rather than scattered over a multitude of isolated topics which never could, in the present state of our knowledge, be in any satisfactory way coördinated.

Ann Arbor, Mich. JOHN AIREY.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 29th, New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society, for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING

Below are given the interpretations of the Committee in Cases Nos. 429 and 431, as formulated at the meeting of October 30, 1923, and in Cases Nos. 423, 426, 428, 432, 433 and 434, inclusive, as formulated at the meeting of December 10, 1923, and approved by the Council. In accordance with practice, the names of inquirers have been omitted.

CASE NO. 423

Inquiry: If an h.r.t. boiler were supported by outside-suspension supports at the rear end, but at the front end the projecting smokebox section of the shell were supported by a structural steel cradle or framework, with ample bearing extending around the circumference to properly distribute the load, is it permissible, under Pars. 323 and 324 of the Boiler Code, to consider it as supported by the equivalent of the outside-suspension type of setting?

Reply: It is the opinion of the Committee that while such construction does not conform to the requirements for the outside-suspension type of setting, the form of support above outlined may be considered the equivalent of suspensions sanctioned by the Code.

CASE NO. 426

Inquiry: Is it permissible, in checking the safety valve capacity of a steam traction engine boiler, under Par. 275 of the Boiler Code, to deduct from the evaporative capacity of the boiler the amount of steam used in the stack steam jet for the forced draft, which jet must be used to develop the maximum evaporative capacity of the boiler and cannot be shut off under an accumulation test if the maximum evaporation is to be obtained?

Reply: The object of the accumulation test specified under Par. 275 is to make sure that there is ample safety valve capacity for any conditions that may exist in service. It is the opinion of the Committee that the test should be made by forcing the fire and driving the engine at its maximum load and then shutting off the engine suddenly with the hottest fire that can be built up with the draft created by exhausting the steam from the engine into the stack; the pressure gage should be watched carefully after shutting down the engine, to note the maximum rise in pressure.

CASE NO. 428

Inquiry: Is it permissible, under the requirements of the Boiler Code, to form a diagonal boiler brace from a single bar of rivet material with integral single rivet ends, that for the head connection being formed straight so as to project directly through the rivet hole, whereas the other being formed at right angles to the brace so as to permit of easy insertion into the hole in the shell after the head rivet end is inserted, and if so, how shall the brace be proportioned under the requirements of the Code?

Reply: It is the opinion of the Committee that for such a design of diagonal brace with single projecting rivet ends, the requirements of Pars. 8 and 223, sections 1, 2 and 8, apply. In the application of this form of diagonal brace, the method of calculation of the stayed surface will be found in Par. 203*a*, in which it is shown that 135 must be used as the value of C in the formula of Par. 199. In the application of diagonal brace of the form described, attention is called to the necessity of carefully insulating any portion of the head or shell that might be heated up if the projecting rivet end is heated in position before riveting.

CASE NO. 429

(Annulled)

CASE NO. 431

Inquiry: When stamping the heating surface on a vertical fire-tube boiler, as required by the National Board of Boiler and Pressure Vessel Inspectors, should the water heating surface as covered by Par. 274 be used, or the total heating surface which includes the superheating surface?

Reply: It is the opinion of the Committee that under Par. 274 of the A.S.M.E. Boiler Code the heating surface to be computed is the water heating surface embracing that below the middle point of the water glass.

CASE NO. 432

Inquiry: Is it permissible, under the requirements of the Heating Boiler Section of the Code, for the fusible plug to be inserted in the front head of a fire-box type of boiler with tubes in a two-pass arrangement so that the plug sets 1 in. above the upper row of tubes, which tubes are inclined upward toward the rear?

Reply: It is the opinion of the Committee that in such a construction as described, the fusible plug may be placed in the front head, provided the requirements of Par. H-64 are met.

CASE NO. 433

Inquiry: Why is Par. H-97, relating to water-relief valves in the Cast-Iron Section of the Heating Boiler Code, different from Par. H-44 of the Steel Plate Section, which also relates to water-relief valves?

Reply: There is a clerical error in Par. H-97, which should read the same as Par. H-44 to state that the valve shall be of the diaphram-operating type without guide wings below the seat.

CASE NO. 434

Inquiry: Will a steam stop valve, the outside screw of which is of the telescoping type, meet the requirements of Pars. 301 to 303 of the Boiler Code? It is pointed out that while the hand-wheel is stationary, the telescoping member rises and falls with the action of the valve and serves as an indicator as to the open or shut position of the valve.

Reply: It is the opinion of the Boiler Code Committee that the valve as described does not meet the requirements in the Code which specify an outside-screw-and-yoke type of valve in which the spindle projects through the hand wheel when the valve is open.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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29 West 39th Street, New York

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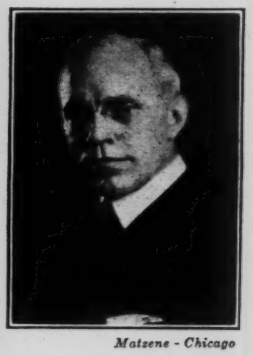
Is Terminal Development a Technical Problem?



Matzene - Chicago

J. R. BIBBINS

ANY one who runs may read the meaning of the gradual drift to the cities of our population, with its increased per capita consumption of farm, building, and industrial products of the country. In fact, this city consumption has dictated and fixed our great railroad and marine gateways. These terminals and gateways have been allowed to grow by accretion rather than by a well-thought-out comprehensive plan, best suited to the needs of our great communities.

It is not far from true that general business, which concerns transportation, doubles in our large cities within 8 to 13 years. The rail tonnage of the country is increasing nearly as the cube of the population (ton-mileage, faster than the cube). Terminal operations must be proportionate to this growth. L. C. L. freight is holding its own in proportion to the total tonnage and requires from 25 to 30 per cent of the country's freight-car equipment to handle from 4 to 5 per cent of the total tonnage. And all of this tremendous movement largely concentrates in terminal zones. Thus it is not an exaggeration to say that, while the transportation demand is increasing nearly as the cube of the population, the *fixed* physical facilities are increasing, if at all, hardly in proportion to the population.

Yet the fact remains that there is no basis today, as there should be, for accurately determining the true investment in these vast terminal properties, nor the actual cost of operation of terminal service as distinct from line haul. But (after much computation and some assumption) I am convinced of this fact: that at least half of the total railroad investment of the country—$10,000,000,000—represents other than main-line facilities, largely terminals, and here also lies perhaps two-thirds of the operating work and worry in railroad operations. We should, of course, consider here only the aggregate true costs, both fixed and operating charges.

It is more of a criticism of our economic system than of the railroads to point out that this vast terminal system has grown up on the competitive plan with great duplication and the overall inefficiencies necessarily resulting therefrom, and that they are and must be operated individually to the best interests of the respective properties until a better plan is conceived. This no doubt is one reason why railroad terminal development has been carried out with so little relation to the broad city plan and that we find today expensive track elevations, both freight houses and team yards, within a stone's throw of our business centers, thus needlessly cluttering our passenger streets, to say nothing of the heavy cost burden loaded upon the traffic passing through these terminals.

In Chicago, railroads occupy more land than commercial business in the central district. This thought suggests that present terminal land values really constitute one of the greatest assets of the railroads today, and if properly developed by more appropriate and intensive usage to their full earning capacity as developed business properties, and with receded freight terminals and motor delivery, they should go far toward financing the rehabilitation of many railroads now laboring under capital shortage. There exist today in various locations, strategic opportunities for the reclamation of these tremendous land assets in entrance rights of way, so that by means of joint development of railroads, rapid transit, and motorways, great new transportation highways can be secured at but a fraction of the combined expense of separate developments for each facility, even if this latter were possible. Such opportunities exist in Chicago, Detroit, and other large cities.

Is more engineering needed in terminal development? This is a pertinent question, in view of the future conditions to be met. How many costly terminal developments have actually been based upon a previous scientific survey of the full facts regarding traffic movement, actual and needed? Hump classification yards often cost $4,000,000 apiece, prewar prices. Yet in two cases recently reported on a reasonably comparative basis, one yard cleared its cars in less than half of the time required by the other. A midwestern road recently found that it cost $8 a car to switch its foreign cars through the gateway, while receiving only $6 per car in per diem rates for this service, and this cost not including fully allocated fixed charges.

It seems evident that one of the greatest needs today is to start work upon adequate metropolitan transportation plans for our large cities and gateways, including all the elements of transportation. Boston, by legislative act, has been the first to visualize this need, and a Transportation Commission is at work, though handicapped like most public commissions by inadequate working funds. The terminal phase is one of the most important in such a study and at the foundation of any adequate development plan is the need for a technical survey of present facilities, traffic movement, costs, and future needs, *before*, not after, more hundreds of millions of new capital are dumped into our terminal systems along obsolete lines of economic development. Such a survey immediately throws light on important points of design and operation such as:

Economic location of lines, break-up yards, and interchanges
Classification yards for different terminal operations
Location and type of local yards and facilities

Woodrow Wilson

The nation is again in mourning for a man whom it distinguished with the highest honor within its power to bestow. The people of the United States twice elected Woodrow Wilson to be their President, the second time as an expression of their confidence in his ability to pilot the nation through one of the most difficult periods of its existence.

The name of Woodrow Wilson is indissolubly linked with the ideal of world peace. With this conception the engineering profession, whose sole passion is to build and construct, is in hearty accord. The manner of accomplishment may be in dispute, but with the ultimate ideal there is no quarrel. The promotion of friendly international relationships in which the engineering profession has had a measure of success is one element in the approach to world peace.

Basis for the comparative study of back haul and dead mileage with reference to the economic size and location of all three above points

Redistribution of belt line and terminal traffic to better advantage

General lines of desirable future development, with possibilities of future unification, rail and marine, and finally

Proper relation of the terminal system to the whole transportation and city plan.

The first detailed survey of such a character of public record, covering every traffic movement in a large port-terminal (New Orleans),[1] revealed an astonishing lack of coöperation between port and railroad operations and the special needs of city freight, and also the clear evidences of the unfortunate results of long years of economic struggle for traffic control—which occurs in every large city. Clearly this illustrates the value and need of the engineering science in future terminal development, and that logical terminal development cannot be brought about by operating men alone when based upon opinion rather than a scientific analysis of the facts from such a traffic survey. The situation demands both engineer and operator.

By 1940 we shall have in this country at least 130,000,000,000 people, with a probable total railroad tonnage of 4,000,000,000 tons as against 2,500,000,000 tons today. To meet this growth at least $10,000,000,000 more will be required for construction and expansion, and probably another $10,000,000,000 for renewals. The main portion of this construction will go into terminals. How it is going to be expended? During the last decade $16,000,000,000 went into highways and motor transport and only $4,000,000,000 into railroads. In the previous decade, the proportion was just the reverse. Obviously there is a need for some keen, far-sighted engineering in the proper allocation of these vast capital expenditures. It will require a much broader vision than has generally prevailed in the past. We must now make one new dollar do the work of two.

Washington, D. C. J. R. BIBBINS.

War Construction Engineers Exonerated

ON JANUARY 30, 1924, Judge A. A. Hoehling, in the Supreme Court of the District of Columbia, completely exonerated the members of the Committee on Emergency Construction of the War Industries Board who were under indictment for conspiracy to control the construction program in the late war.

Judge Hoehling's decision, dismissing the indictments, contained the statement that the charges abounded in the statement of conclusions unsupported by facts. In effect, he condemned the atmosphere of graft and crime intimated in the language of the indictments without supporting facts, and which was disseminated widely in the daily press at the time of the action by the Attorney General. The opinion says that the desirable results of getting construction done were certainly produced, and quotes from the report of the Secretary of War Baker to the President in 1918:

> In spite of the stupendous difficulties involved, the entire housing (for the Army) enterprise was completed on schedule, constituting one of the most remarkable accomplishments of the War.

In December, 1922, indictments were brought against Benedict Crowell, Cleveland, former Assistant Secretary of War; William A. Starrett, New York; C. W. Lundoff, Cleveland; Morton C. Tuttle, Boston; John H. McGibbons, Chicago; Clair Foster, New York; and James A. Mears, New York. The charges were numerous but the Government admitted in its argument that the only offense charged was a conspiracy to defraud the United States by prejudicing the orderly administration of its laws by the regularly constituted officers. The adoption of the cost-plus contract and the elimination of competitive bidding was thus made the basis of the action. The ruling of Judge Hoehling makes it quite plain that the decision in these matters of policy was made by the Secretary of War in proper legal form and points out "that it would be a highly dangerous thing to submit to judicial review a question of departmental action and policy such as is here attempted."

Judge Hoehling discussed the form of contract in question at length and pointed out that there were ample and even unusual safeguards for the Government's interest. Apparently the only safeguards that Government's representatives could allege were not covered were in a possible bonus and penalty clause, claims under which type of clause some other governmental departments are now trying to repudiate.

While directed against individuals, the indictments were actually against the ability of the American people to make successful use of its qualified citizens in carrying out the tremendous tasks of a national emergency. Furthermore, the indictments were brought in spite of the approval in March, 1918, of the form of contract for emergency construction by a committee appointed by the War Department to review the situation at that time, of which the then presidents of the American Society of Civil Engineers, The American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Architects, the United States Chamber of Commerce, the American Federation of Labor, and the General Contractors Associations of New York and of Chicago, were members. In July, 1918, the Secretary of War appointed a Board of Review which, after extensive investigations both in Washington and on jobs of various types, again recorded approval of the form of contract and reported that the execution of the construction program had been a remarkably successful piece of work. In the face of such opinions, the charges were purely partisan and as now disclosed were mere allegations unfounded on fact.

In the spring of 1923 it became apparent that court action on the charges was being allowed to lag and that the victims would be compelled to suffer indefinitely under the shadow of the indictments. It was only after many engineering and similar organizations, including The American Society of Mechanical Engineers, had urged prompt trial, that the matter was brought into court. The harm done by these unsupported indictments can only be partly relieved by widespread publicity of their dismissal. Then there are still the suits against the eleven contractors who built cantonments. The claims in these suits aggregate many millions of dollars. The general atmosphere of these suits is the same as that of the indictments just dismissed. The progress of these suits is dragging even more than those of the indictments. It is the duty of all to exert pressure on those in authority to clear up these suits to the end that justice be done.

Preparedness Plans of Corps of Engineers

PLANS for procuring engineer material for war purposes are being developed by the Corps of Engineers, which should materially lessen the confusion usually incident to such undertakings if the United States finds itself in any future emergency. The purchase and transportation of supplies for the army in the Great War was a monumental task and owing to a lack of any commensurate plan, considerable confusion and delay resulted.

Experiences of the war years showed a need for closer coöperation and coördination between the army and the industrial resources of the country. The Assistant Secretary of War, who has supervision of all war-procurement activities of the army, has instructed the various supply branches of the army to prepare plans that can be woven together into a general plan for industrial mobilization. For the procurement of supplies for the Corps of Engineers, the country has been divided into six industrial districts with headquarters at each of the following cities: Schenectady, New York City, Philadelphia, Pittsburgh, Chicago, and San Francisco. An engineer officer now on duty has been designated to have charge of peace-time activities in each of these cities.

It is the plan to develop in each district an organization of Engineer Reserve Officers with entire responsibility for the procurement of necessary material and supplies used by the Corps of Engineers that are produced within the limits of the district. A central organization located in the office of the Chief of Engineers at Washington will coördinate and control the activities of the various procurement districts.

An engineering and development branch, consisting principally of scientists and engineers, is embodied in the plans for the central organization. It is hoped that the present plans may serve to keep alive the friendly coöperation of these men with the War Department.

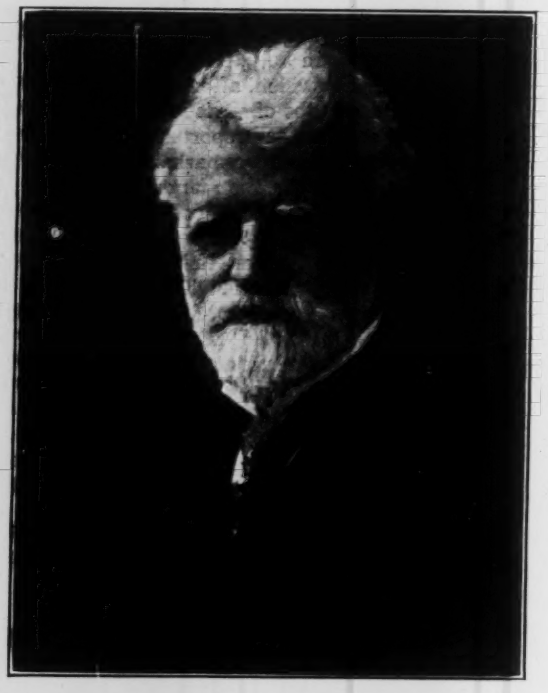
[1] See writer's paper, American Association of Port Authorities, Dec., 1923.

Ambrose Swasey Awarded the John Fritz Gold Medal

THE 20th award of the John Fritz Gold Medal was made on January 18 to Ambrose Swasey, of Cleveland, Ohio, for the building of great telescopes, benefactions to education, founding of Engineering Foundation, and the invention and manufacture of fine machine tools, precision instruments, and military and naval range finders.

This medal was established in 1902 in honor of John Fritz, one of the great pioneers in the American iron and steel industry. It is awarded annually for notable scientific or industrial achievement and is the highest honor bestowed by the engineering profession in this country.

Mr. Swasey is vice-chairman of the Board of the Warner & Swasey Company. He was one of the organizing members of The American Society of Mechanical Engineers, of which is a past-president and honorary member. He is also an honorary member of the American Society of Civil Engineers and of several other engineering societies of America and Europe. He is an Officer of the Legion of Honor, of France, and has been the recipient of many other honors. He is a member of the National Academy of Sciences and of the National Research Council, and a Fellow of the Royal Astronomical Society, of England.



AMBROSE SWASEY

The most notable of his many public benefactions was the establishment of Engineering Foundation as the joint research instrumentality of the four great national societies of civil, mining and metallurgical, mechanical, and electrical engineers.

Among the remarkable telescopes built by his company are the 36-in. Lick refractor at Mt. Hamilton, Cal., the 26-in. telescope of the Naval Observatory at Washington, the 40-in. telescope of the Yerkes Observatory at Williams Bay, Wis., and the 72-in. reflecting telescope of the Dominion Astronomical Observatory at Victoria, B. C.

Ambrose Swasey was born in Exeter, N. H., December 19, 1846, of New England lineage. He worked at the machinist's trade in Exeter and in the Pratt & Whitney Company's shops at Hartford, Conn. In these early years he met Worcester R. Warner, who became his lifelong friend and partner. About 1880 they went to Chicago, but soon concluded that Cleveland was the more suitable location for their intended business.

Mr. Swasey has been an extensive traveler and his interests have been correspondingly broad.

The John Fritz Gold Medal has heretofore been awarded to the following distinguished engineers:

John Fritz	John Edson Sweet
Lord Kelvin	James Douglas
George Westinghouse	Elihu Thomson
Alexander Graham Bell	Henry Marion Howe
Thomas Alva Edison	J. Waldo Smith
Charles T. Porter	George W. Goethals
Alfred Noble	Orville Wright
Sir William Henry White	Sir Robert A. Hadfield
Robert W. Hunt	Guglielmo Marconi

Charles Prosper Eugene Schneider

Dr. Elihu Thomson to Receive the Kelvin Gold Medal

FORMAL presentation of the Kelvin Gold Medal to Dr. Elihu Thomson, Past-President of the American Institute of Electrical Engineers, will be made in London in July during the Kelvin Centenary Celebration. The Kelvin Gold Medal is awarded triennially as a mark of distinction to a person who has reached eminence as an engineer or investigator in the kind of work applicable to the advancement of engineering with which Lord Kelvin was especially identified. The Medal was first awarded in 1920 when Dr. William Cawthorne Unwin, F.R.S., of London, was the recipient.

Dr. Thomson was born in Manchester, England, in 1853, but came to the United States when but five years old. His formal education was received in the public schools of Philadelphia. At an early age he became interested in experiments in electricity and constructed his first practical dynamo for a course of lectures he delivered at Franklin Institute during the winter of 1876–77. Almost half a century has elapsed since the construction of his first dynamo, and in that time Dr. Thomson has been granted approximately 700 United States patents, most of which have been for inventions in the electrical field.

Among his inventions may be mentioned: the three-coil armature for dynamos and motors; the constant-current regulator for arc-lighting dynamo; the induction motor; the magnetic blowout for switches; lightning arrestors of various forms; and the constant-current transformer.

Although Dr. Thomson's long service in the field of electrical engineering has caused him to be regarded as the dean of electrical engineers in this country, his contribution to science has by no means been limited to this one field. His developments in the realm of mechanical engineering, especially in connection with welding, steam turbines, steam engines and internal-combustion engines, have been noteworthy. The science of chemistry bears his imprint. As an educator his influence has been dominant, for his methods have been those which carry a problem from the realm of theory to the field of practical accomplishment. His life work in science has been of a broad and international character. His ideal of service has advanced not only the engineering profession but the welfare of man.

As a result of some of Dr. Thomson's earlier tests and inventions, which were made in coöperation with Professor Houston at Franklin Institute, an improved electric-lighting apparatus was developed and a company organized in 1880 to make practical use of it. This company, known as the American Electrical Company, became in 1882 the Thomson-Houston Electric Company. The perfection of its electric-lighting apparatus continued and his arc-lighting dynamo and arc lamp were installed in many of the lighting plants in this country and Europe. In 1892 the interests of the Thomson-Houston Company and the Edison interests were consolidated and the new company became the General Electric Company. Dr. Thomson has been continuously associated with this company ever since, and is at present the director of their Thomson Laboratory located at Lynn, Mass.

The award of the Kelvin Gold Medal, one of the most highly regarded trophies of the world of science, comes as the culmination of a long list of honors which have been showered upon Dr. Thomson in recognition of his work. The committee which makes the award consists of the presidents of the principal engineering societies of

Great Britain. The four national engineering societies of America were asked to submit nominations for the 1923 award, and it is gratifying to American engineers that the British Committee should have seen fit to bestow the Medal on an American scientist who was nominated by representatives of American engineering societies.

Dr. Thomson is a member and honorary member of many scientific societies both here and abroad. He was awarded the Grand Prix in Paris, 1889–90, for electrical inventions; decorated Chevalier and Officer of the Legion of Honor in 1889 by the French Government for electrical research and inventions; received the Grand Prize in St. Louis in 1904 for electrical work; the Rumford Medal in 1902; the first Edison Medal in 1909; the Elliot Cresson Medal; the John Fritz Medal; and the Hughes Medal of the Royal Society, London, 1916.

Edison Medal Awarded to John W. Lieb at 40th Anniversary Meeting of A.I.E.E.

THE Fortieth Anniversary of the American Institute of Electrical Engineers was celebrated at its midwinter convention in Philadelphia, February 4–8, 1924. On the first evening of the meeting there was a very interesting series of addresses on the early history of the Institute by Elmer A. Sperry, T. Commerford Martin, Elihu Thomson, and John J. Carty. These addresses were followed by the presentation of the Edison Medal to John W. Lieb, former vice-president of the A.S.M.E. "for the development and operation of electric central station for illumination and power." Mr. Lieb has been identified from the very beginning with the design and construction of central power stations. The presentation address was made by Samuel Insull. The medal has been previously awarded to Elihu Thomson, Frank J. Sprague, George Westinghouse, William Stanley, Charles F. Brush, Alexander Graham Bell, Nikola Tesla, John J. Carty, Benjamin G. Lamme, W. L. R. Emmet, Michael I. Pupin, Cummings C. Chesney, and Robert Andrews Millikan.

Mr. Lieb is a graduate of Stevens Institute in the class of 1880. In 1882 he was associated with Mr. Edison in experimental work and became electrician in charge of installation and operation at the Pearl Street Station of the Edison Electric Illuminating Company of New York. From 1883 to 1894 he was engaged in power-station work, lamp and apparatus manufacture, and the development of long-distance transmission in Italy, returning to New York as assistant to the vice-president of the Edison Electric Illuminating Company. Later he became vice-president of the New York Edison Company, in charge of operation. He is a fellow of the American Institute of Electrical Engineers and served as president in 1904–05. He belongs to many scientific and engineering societies in this country and abroad.

The dedication ceremonies of the Moore School of Electrical Engineering at the University of Pennsylvania were a part of the convention program. Through the provision of Alfred Fitter Moore a fund of $1,500,000 was left to the electrical engineering department of the university. By utilizing the present excellent equipment of buildings and apparatus, the entire sum bequeathed can be used almost entirely for instruction. The speakers at the dedication were Mr. Herbert T. Herr, on the Electrical Engineer and His Relation to the Progress of the World, and Dr. Arthur M. Greene, Jr., on Engineering Education, Its Present State and Ideals. Honorary degrees were conferred as follows: Doctor of Laws, to John Joseph Carty, Frank Julian Sprague, Elihu Thomson, and Edward Weston; Doctor of Science, to Robert Hayward Fernald and Harold Pender. Professor Fernald, who is director of the course in mechanical engineering at the university, was greeted as an inspiring teacher and one who brought great credit to the profession through his participation in public affairs.

The feature session at the meeting was one on Transportation which was addressed by E. G. Buckland, vice-president of the N. Y. N. H. & H. R. R., on The Place of Transportation on Civilization; Francis H. Sisson, vice-president of the Guaranty Trust Co., New York, on The Credit Question in Transportation; Ralph Budd, president of the Great Northern R. R., on Transportation and the Rural Situation; H. B. Thayer, president American Telephone & Telegraph Co., on The Public's Transportation Problem; and A. J. County, vice-president Pennsylvania R. R., on Solid Foundations for Better and Cheaper Transportation Service.

Ten technical sessions were held during the five days of the meeting, which was followed by a visit to the Bethlehem Steel Company.

Posthumous Award to Steinmetz

A POSTHUMOUS award of £1000 has been made to Charles P. Steinmetz by the trustees of the Benjamin Franklin Fund for his privately published treatise, The Nervous System as a Conductor of Electrical Energy. Announcement of the first awards of this Fund recalls to mind the unusual circumstances under which it had its inception.

About 165 years ago when Franklin was in England as a representative for the American Colonies, he put £100 in the hands of members of the Society of Friends with instructions that it was to be invested and allowed to accumulate for a period of not less than 150 years. Thereafter awards were to be made from time to time at the discretion of the trustees for the most valuable contributions to science, either published or in manuscript form, on the general subject of cures, with particular emphasis on surgery, the nervous system, and the part that mind treating might have on the recovery and preservation of health. The initial awards, as announced the latter part of January, totaled £4000.

The major award went to Pierson W. Banning, of Los Angeles, for his Mental and Spiritual Healing, All Schools and Methods, A Textbook for Physicians and Metaphysicians. A third award went to Fusakichi Omori, of Japan, for an unpublished treatise on The Rotary Knife in Surgery.

New Officers of John Fritz Medal Board of Award

CHARLES F. RAND, Past-President of the American Institute of Mining and Metallurgical Engineers, has been elected chairman of the John Fritz Medal Board of Award. Mr. Rand has served as a member of the Board for eight years and was its secretary for several years. Fred J. Miller, one of the A.S.M.E. representatives on the Board, succeeds Mr. Rand as secretary.

The John Fritz Medal Board of Award consists of sixteen members—four representatives from each of the four national engineering societies. At present the personnel of the Board is as follows:

A.S.C.E.; A. P. Davis, George S. Weber; John R. Freeman, C. F. Loweth.

A.I.M.E.; Herbert Hoover, B. B. Thayer, A. F. Dwight, Chas. F. Rand.

A.S.M.E.; Walter M. McFarland, W. F. M. Goss, F. J. Miller, Henry B. Sargent.

A.I.E.E.; A. W. Berresford, Frank B. Jewett, William McClellan, Frank J. Ryan.

Formal Opening of New Aerodynamic Laboratory at Toronto University

THE new Aerodynamic Laboratory in the Department of Mechanical Engineering of the University of Toronto, Canada, was formally opened on Friday, February 8, 1924, at 4.00 p.m. Maj.-Gen. J. H. MacBrien, Chief of Staff, Department of National Defense, and Brig.-Gen. C. H. Mitchell, Dean of the Faculty of Applied Science of the University, officiated.

The opening of this building, which houses the wind channel, permits research in aerodynamics and allied subjects the whole year round instead of during the summer months only. The channel, which was formerly housed in the Hydraulic Laboratory, has been altered, and now permits speeds up to ninety feet per second in the working section. This is the only equipment of its kind in Canada, and is frequently made use of by the Royal Canadian Air Force to provide data on proposed designs which could not be obtained in any other way, and by manufacturers for various test work.

Reprints from Annual Tables of Constants

REPRINTS of the Annual Tables of Constants and Numerical Data of Physics, Chemistry, and Technology are available now as announced below.

These critical tables are a part of an international plan to assemble scientific data. At a meeting of the International Union of Pure and Applied Chemistry held in London in 1919, the American delegates submitted a plan for the international compilation of a set of volumes of critically prepared tables of the physical and chemical properties of materials of importance to the pure scientist and the engineer. The National Research Council undertook entire financial and editorial supervision and sponsorship for the project, which met the approval of the Union.

Every corporation which employs engineering service is penalized in time and money by the handicaps under which their engineers must work when they must assemble their own information of the characteristics of materials. For example, in making bleaching powder by a continuous process, considerable heat is evolved in the reaction of chlorine with calcium hydroxide to form the bleaching powder. The "constants" for the heat of the reaction are important and, if not available, the establishment of the process will be delayed until they are determined. This is one of many instances where The Annual Tables of Constants would be of great value.

Not America alone but the whole world is working at a disadvantage for the want of such tables of constants. Through the National Research Council an International Commission is at work compiling this valuable and original contribution to our scientific knowledge.

The reprints listed below are found in Volume IV of Annual Tables, which volume covers the literature of the world for the years 1913 to 1916, inclusive. Members of The American Society of Mechanical Engineers are entitled to a fifty per cent discount on the prices quoted. Orders should be sent to Dr. Charles Marie, 9 Rue de Bagneux, Paris, and should be accompanied by an international money order or a draft on Paris covering the price of the reprint plus 2 francs for postage and packing on each order.

	Pages	Price in Francs Paper	Bound
Spectroscopy, by M. L. Brüninghaus. Preface by A. Fowler, F.R.S.	210	35	45
Electricity, Magnetism, Conductivity of Electrolytes, Electromotive Forces, by Mm. Malapert, v. Weisse, R. E. Slade and G. L. Higgen. Preface by F. B. Jewett	144	30	40
Radioactivity, Electronics, Ionization of Gases, etc., by Mm. J. Saphores and F. Bourion. Preface by Sir E. Rutherford, F.R.S.	19	10	18
Crystallography and Mineralogy, by L. J. Spencer. Preface by Sir Henry A. Miers, F.R.S.	65	15	25
Biology, by E. Terroine and H. Colin. Preface by Jacques Loeb	37	12	20
Engineering and Metallurgy, by L. Descroix. Preface by G. K. Burgess	154	30	40
Colloids, by E. Rebiere. Preface by Jacques Duclaux	9	6	12

Opening of the American Safety Museum

THE American Museum of Safety, which since 1920 has had its exhibits stored, reopened in new quarters at 120 East 28th Street, New York City, on January 15, 1924, in the presence of pioneers of the safety movement, captains of industry, and state officials. Almost a thousand people visited the museum the first afternoon to see the hundreds of devices that are being used in industrial plants, mines, railroads, and public utilities throughout the country to safeguard the life and limbs of workmen.

At a luncheon meeting preceding the opening, attended by the Board of Trustees, Arthur Williams, president of the museum, announced that James Speyer, the treasurer, had authorized the use of $50,000 which he had donated as a nucleus of a building fund for the maintenance of the present museum until such time as it is possible to erect a new building. Mr. Williams also announced that the *Scientific American* offers a gold medal again for the best safety device exhibited in the museum for 1924. The museum itself will award the Louis Livingston Seaman Medal this year for the best industrial-sanitation work of the year.

During the past year A. A. Hopkins, director of the museum, has been engaged in collecting from industrial centers throughout the country specimens of safety devices, materials, and equipment which are proving most effective in the prevention of accidents, and graphic exhibits of educational methods which show the greatest reduction in accidents. There is no question but that the museum will become an educational center for employers, and as a result the annual toll of accidents in the United States will grow less and less.

U. E. S. Report for 1923

AT THE annual meeting of United Engineering Society, January 24, 1924, the following officers were unanimously elected: President, W. L. Saunders; First Vice-President, George H. Pegram; Second Vice-President, J. V. W. Reynders; Secretary, Alfred D. Flinn; Treasurer, Joseph Struthers; Assistant Treasurer, Henry A. Lardner. *Finance Committee:* George H. Pegram, *Chairman*, J. Vipond Davies, W. F. M. Goss, Bancroft Gherardi, and the President, ex-officio.

The membership of the Board of Trustees for 1924 is as follows:

Representing the Civil Engineers: W. J. Wilgus; George H. Pegram; Lewis D. Rights.

Representing the Mechanical Engineers: W. L. Saunders; W. F. M. Goss; James H. Herron.

Representing the Mining Engineers: J. Vipond Davies; J. V. W. Reynders; Walter H. Aldridge.

Representing the Electrical Engineers: Bancroft Gherardi; Henry A. Lardner; H. H. Barnes, Jr.

Below is a summary of the report of the treasurer of the U. E. S. for the calendar year 1923.

SUMMARY

Operation of Building

Credit balance January 1, 1923		$ 16,800.78
Building revenue	$113,439.74	
Building expenditures	94,422.08	
Operating balance for year	$ 19,017.66	
Securities purchased for Dep. & Ren. Fund	19,754.73	−737.07
		$ 16,063.71
Uncollectable accounts written off	564.00	
Addition to real estate	7,428.77	7,992.77
Credit balance Dec. 31, 1923		$ 8,070.94

Operation of Library

Library Revenue:		
Maintenance and Recataloging	$ 45,452.25	
Service Bureau	16,551.27	$62,003.52
Library Expenditures:		
Maintenance and recataloging	$ 44,626.21	
Service Bureau	15,513.69	60,139.90
		$ 1,863.62
Less accounts charged off and adjustments		51.41
Credit balance Dec. 31, 1923		$ 1,812.21

Funds and Property

Funds held by U. E. S. Dec. 31, 1923 (book value):	
Depreciation and Renewal	$159,339.94
Engineering Foundation	502,066.05
Library Endowment	93,351.25
General Reserve	10,000.00
John Fitz Medal (U. E. S. custodian)	3,500.00
Total	$ 768,257.24
Real estate owned by U. E. S., cost to December 31, 1923	1,966,569.44
Operating cash in bank	5,427.90
Accounts receivable	4,510.14
Value of Library (as appraised for insurance)	329,000.00
Total property for which U. E. S. is trustee or custodian	$3,073,764.72

A Correction

ON PAGE 38 of the January issue of MECHANICAL ENGINEERING it was stated that the paper on Resistance of Various Aluminum Alloys to Salt-Water Corrosion by D. Basch and M. F. Sayre was published in the December, 1923 issue. This paper did not appear in that issue but is scheduled for publication in the near future.

Engineering and Industrial Standardization

Simplified Practice Recommendations on Lumber

GOOD progress in the adoption of standards by the lumber industry was recorded at a recent general conference in Washington. This was the third conference in the series which the Department of Commerce, Division of Simplified Practice, had conducted with the complete coöperation of the Central Committee on Lumber Standards and the Forest Service of the Department of Agriculture. A full statement concerning the organization of this Committee and its Consulting Committee was given in the July, 1923, issue of MECHANICAL ENGINEERING.

The Committee's work is not as yet entirely finished, but it now presents for adoption, by all interests concerned, recommendations covering:

I Standard Lumber Classifications
II Standard Grade Names and Classifications
III Standard and Extra Standard Yard Lumber Sizes
IV Methods of Lumber Measurement
V Shipping and Other Provisions

I—STANDARD LUMBER CLASSIFICATIONS

The report defines "lumber" as the product of saw and planing mill not further manufactured than by sawing, resawing, and passing lengthwise through a standard planing machine, cross-cut to length and matched, and it recognizes three methods of classifying lumber, viz., by (1) use, (2) size, and (3) manufacture.

By the first method lumber is classified as (*a*) Yard Lumber, (*b*) Structural Timbers, and (*c*) Shop or Factory Lumber. Different grading rules may apply to each class of lumber, as follows:

(*a*) *Yard Lumber:* Lumber that is less than 6 in. in thickness and is intended for general building purposes. The grading of yard lumber is based upon the use of the entire piece.
(*b*) *Structural Timbers:* Lumber that is 6 in. or over in thickness and width. The grading of structural timbers is based upon the strength of the piece and the use of the entire piece.
(*c*) *Shop or Factory Lumber:* Lumber intended to be cut up for use in further manufacture. It is graded on the basis of the percentage of the area which will produce a limited number of cuttings of a given minimum size and quality.

When classified by *size* we find yard lumber and structural timbers subdivided as follows:

(*a*) *Strips:* Yard lumber less than 2 in. thick and under 8 in. wide.
(*b*) *Boards:* Yard lumber less than 2 in. thick, 8 in. or over in width.
(*c*) *Dimension:* All yard lumber except boards, strips, and timbers; that is, yard lumber 2 in. and under 6 in. thick, and of any width.
  (1) Planks: Yard lumber 2 in. and under 4 in. thick and 8 in. and over wide.
  (2) Scantlings: Yard lumber 2 in. and under 6 in. thick and under 8 in. wide.
  (3) Heavy Joists: Yard lumber 4 in. and under 6 in. thick and 8 in. or over wide.
(*d*) *Timbers:* Lumber 6 in. or larger in least dimension.

Manufactured lumber is classified in the report as (*a*) rough, (*b*) surfaced, and (*c*) worked. The following definitions of these three classes form part of the report:

(*a*) *Rough Lumber:* Undressed as it comes from the saw.
(*b*) *Surfaced Lumber:* Lumber that is dressed by running through a planer. It may be surfaced on one side (S1S), two sides (S2S), one edge (S1E), two edges (S2E) or a combination of sides and edges (S1S1E), (S2S1E), or (S1S2E) or (S4S).
(*c*) *Worked Lumber:* Lumber which has been run through a matching machine, sticker, or molder. Worked lumber may be (1) matched, (2) shiplapped, or (3) patterned:
  (1) Matched Lumber: Lumber that is edge dressed and shaped to make a close tongue-and-groove joint at the edges or ends when laid edge to edge or end to end.
  (2) Shiplapped Lumber: Lumber that is edge dressed to make a close rabbeted or lap joint.
  (3) Patterned Lumber: Worked lumber that is shaped to a patterned or molded form.

II—STANDARD GRADE NAMES AND CLASSIFICATIONS

The term "yard lumber" as here used means lumber that is manufactured and classified into those sizes, shapes, and qualities required for ordinary construction and general-purpose uses. (Heavy timbers for structural purposes, softwood factory lumber, hardwood factory lumber, and other special-use materials are not considered yard stock.)

On the basis of quality, yard lumber is divided into two main divisions: (*a*) Select lumber and (*b*) common lumber. These are again divided into two classes—Select lumber into (1) that suitable for natural finishes (Grades A and B) and (2) that suitable for paint finishes (Grades C and D). Common lumber into (1) that which can be used without waste (Grades 1 and 2), and (2) that which permits some waste (Grades 3, 4 and 5).

III—STANDARD AND EXTRA STANDARD YARD LUMBER SIZES

One-inch ($^{25}/_{32}$) boards and two-inch ($1^{5}/_{8}$) dimension are the most generally used sizes of ordinary surfaced yard lumber. The boards are used largely for covering purposes, the dimensions largely for framing purposes. These two sizes are basic. Around them for five years has centered most of the controversey over sizes. If these two basic sizes can be standardized in actual practice, the standard sizes of most of the other—less important—items can be more readily maintained.

The Committee's recommendation contemplates that for ordinary covering and general-utility purposes the consuming public should be encouraged to use Standard Board. This would be not less than $^{25}/_{32}$ in. thick in commercially dry condition, dressed on either one or two sides.

Similarly, for ordinary framing and bracing purposes, etc., the consuming public should be encouraged to use Standard Dimension. This would be not less than $1^{5}/_{8}$ in. thick, dressed on either one or two sides.

It is not intended that the terms "1-in. boards" and "2-in. dimension" be discontinued because, obviously, the Standard Board and Standard Dimension are measured as 1 in. and 2 in., board measure, respectively. Furthermore, these designations are firmly fixed in the lumber trade and it is the Committee's thought that existing custom and practice, unless unsound, illogical, or unreasonable should not be disturbed.

The use of the term Standard Board, therefore, is advocated not because it happens to have been made from 1-in. lumber in its rough green condition, but because it represents the best and most practical size for the ordinary general-utility purposes of the consumer and should therefore be described to him as such.

Similarly with the Standard Dimension. If the average lumber user can be gradually educated to use Standard Boards and Standard Dimension for his ordinary purposes, it is believed that he will benefit thereby, and the maintenance of these size standards will have become much more effective.

Therefore, no board thinner than $^{25}/_{32}$ in., thick, dry and surfaced, should be sold as a Standard Board; and no dry, surfaced dimension less than $1^{5}/_{8}$ in. thick should be sold as Standard Dimension.

The use of the description "Standard" is in accord with the purpose of the Committee to focus the mind of the consumer upon the advantages and economy of confining his purchases to lumber of standard size. It should have educational value and should have the effect of emphasizing to the consumer the superior utility or use value of the Standard Board and the Standard Dimension.

The following is a part of the Committee's revised report on this part of the subject.

III—*Standard and Extra Standard Yard Lumber Sizes.* The terms "standard board" and "extra standard boards" and "standard dimension and extra standard dimension" shall be the designations for 1-in. boards (yard) and 2-in. dimension (yard), respectively, and applied to both softwoods and hardwoods.

$^{25}/_{32}$-in., S1S or S2S (measured at standard commercially dry shipping weight and moisture content for each species) shall be

the thickness for the standard yard board; $^{26}/_{32}$ in., S1S or S2S, for the extra standard yard board.

$1^{5}/_{8}$ in., S1S or S2S (measured at standard commercially dry shipping weight and moisture content for each species) shall be the thickness for standard dimension not more than 12 in. wide; $1^{3}/_{4}$ in., S1S or S2S, for extra standard dimension.

The finished widths of boards, dimension and finish S1E or S2E (measured at standard commercially dry shipping weight and moisture content for each species) shall be $^{3}/_{8}$ in. off on lumber of standard widths less than 8 in. and $^{1}/_{2}$ in. off on lumber of standard widths of 8 inches and over.

The thicknesses and widths of finished lumber shall be as follows:

SUMMARY OF STANDARD AND EXTRA STANDARD SIZES FOR YARD LUMBER, S1S OR S2S, S1E OR S2E

(The thicknesses apply to all widths and the widths to all thicknesses)

	Size, board measure		Dressed dimensions at standard commercially dry shipping weight and moisture content		
			Thickness, extra		
Product	Thickness, inches	Width, inches	Thickness, standard, inches	inches	Width, inches
Finish		3	$^{5}/_{16}$		$2^{5}/_{8}$
		4	$^{7}/_{16}$		$3^{5}/_{8}$
		5	$^{9}/_{16}$		$4^{5}/_{8}$
		6	$^{11}/_{16}$		$5^{5}/_{8}$
	1	7	$^{25}/_{32}$	$^{26}/_{32}$	$6^{5}/_{8}$
	$1^{1}/_{4}$	8	$1^{1}/_{16}$		$7^{1}/_{2}$
	$1^{1}/_{2}$	9	$1^{5}/_{16}$		$8^{1}/_{2}$
	$1^{3}/_{4}$	10	$1^{7}/_{16}$		$9^{1}/_{2}$
	2	11	$1^{5}/_{8}$	$1\ ^{3}/_{4}$	$10^{1}/_{2}$
	$2^{1}/_{2}$	12	$2^{1}/_{8}$		$11^{1}/_{2}$
	3		$2^{5}/_{8}$		
Common Boards	1	3	$^{25}/_{32}$	$^{26}/_{32}$	$2^{5}/_{8}$
	$1^{1}/_{4}$	4	$1^{1}/_{16}$		$3^{5}/_{8}$
	$1^{1}/_{2}$	5	$1^{5}/_{16}$		$4^{5}/_{8}$
	2	6	$1^{5}/_{8}$	$1\ ^{3}/_{4}$	$5^{5}/_{8}$
		7			$6^{5}/_{8}$
		8			$7^{1}/_{2}$
		9			$8^{1}/_{2}$
		10			$9^{1}/_{2}$
		11			$10^{1}/_{2}$
		12			$11^{1}/_{2}$
Dimension	2	2	$1^{5}/_{8}$	$1\ ^{3}/_{4}$	$1^{5}/_{8}$
	$2^{1}/_{2}$	4	$2^{1}/_{8}$		$3^{5}/_{8}$
	3	6	$2^{5}/_{8}$		$5^{5}/_{8}$
	4	8	$3^{5}/_{8}$		$7^{1}/_{2}$
	Over 4	10	Off $^{3}/_{8}$		$9^{1}/_{2}$
		12			$11^{1}/_{2}$

FACTORY FLOORING, HEAVY ROOFING, DECKING, AND SHEET PILING

(Thicknesses apply to all widths and the widths to all thicknesses)

Size, board measure		Dressed dimensions at standard commercially dry shipping weight and moisture content			
			Face width		
Thickness, inches	Width, inches	Thickness,[1] inches	D. & M., inches	Shiplapped, inches	Grooved for splines, inches
2	4	$1^{5}/_{8}$	$3^{1}/_{2}$	3	$3^{1}/_{2}$
$2^{1}/_{2}$	6	$2^{1}/_{8}$	$5^{1}/_{2}$	5	$5^{1}/_{2}$
3	8	$2^{5}/_{8}$	$7^{1}/_{2}$	7	$7^{1}/_{2}$
4	10	$3^{5}/_{8}$	$9^{1}/_{2}$	9	$9^{1}/_{2}$
	12		$11^{1}/_{2}$	11	$11^{1}/_{2}$

[1] Minimum.

IV—Methods of Lumber Measurement

The Committee's recommendation in regard to odd- and short-length lumber is that the matter be held for subsequent and separate determination after Committee conferences may have developed a closer approach to agreement among the representatives of various branches of the lumber trade and the lumber consumers, than now apparently exists.

The following thicknesses and widths of yard lumber shall be considered *standard*. All other sizes shall be considered *special:*

THICKNESSES: $^{5}/_{16}$, $^{7}/_{16}$, $^{9}/_{16}$, $^{11}/_{16}$, 1, $1^{1}/_{4}$, $1^{1}/_{2}$, $1^{3}/_{4}$, 2, $2^{1}/_{2}$, 3, $3^{1}/_{2}$, 4 in. board measure and up in multiples of 1 in.; for rustic, drop siding and partition, $^{3}/_{4}$ in.; for bevel siding, $^{1}/_{2}$ by $^{3}/_{16}$ and $^{5}/_{8}$ by $^{3}/_{16}$ in.

WIDTHS: 1 in. and up, board measure, in multiples of 1 in.

Yard lumber of standard and extra standard size shall be described by these standard dimensions. Lumber of standard and extra standard size shall be tallied board measure. On lumber of standard thickness less than 1 inch (board measure) the board foot measurement shall be based on the surface dimensions

The board measurement of dressed lumber of standard and extra standard size shall be based upon the corresponding standard dimensions of rough green lumber. Lumber finished to special size shall be counted (tallied) as of the standard rough size necessarily used in its manufacture.

The measurement and description of the dimensions of yard lumber shall be as given in the following table:

Thickness of yard lumber measured and described as—	Minimum thickness, S1S or S2S; at standard commercially dry shipping weight and moisture content, in.
1 in., board measure, to be not less than	$^{25}/_{32}$
$1^{1}/_{4}$ in., board measure, to be not less than	$1^{1}/_{32}$
$1^{1}/_{2}$ in., board measure, to be not less than	$1^{9}/_{32}$
$1^{3}/_{4}$ in., board measure, to be not less than	$1^{7}/_{16}$
2 in., board measure, to be not less than	$1^{5}/_{8}$
$2^{1}/_{2}$ in., board measure, to be not less than	$2^{1}/_{8}$
3 in., board measure, to be not less than	$2^{5}/_{8}$
$3^{1}/_{2}$ in., board measure, to be not less than	$3^{1}/_{8}$
4 in., board measure, to be not less than	$3^{5}/_{8}$

Widths of boards, dimension and finish, measured and described as 2, 3, 4, 5, 6, and 7 in., board measure, to be, respectively, not less than $1^{5}/_{8}$, $2^{5}/_{8}$, $3^{5}/_{8}$, $4^{5}/_{8}$, $5^{5}/_{8}$, $6^{5}/_{8}$ in., S1E or S2E, at standard commercially dry shipping weight and moisture content; widths of boards, dimension and finish, measured and described as 8, 9, 10, 11 and 12 in., board measure, to be, respectively, not less than $7^{1}/_{2}$, $8^{1}/_{2}$, $9^{1}/_{2}$, $10^{1}/_{2}$ and $11^{1}/_{2}$ in.

The description of thickness of dressed stock less than 1 in. thick, board measure, S1S or S2S, to be its actual thickness at standard commercially dry shipping weight and moisture content.

It is to be understood that the standard dimensions of rough lumber, commercially dry, are in excess of the dimensions of finished lumber of the corresponding size, board measure, by the amount necessary to permit of surfacing either one side or two sides and / or one edge or two edges.

V—Standard Shipping Weights

The report provides that "the standard weights to be used in determining thickness and width shall be the commercially dry shipping weights of the regional groups of manufacturers issued after approval by the Central Committee on Lumber Standards and in effect when shipment is made."

Historical[1]

What might be termed the present lumber standardization movement within the lumber industry itself had its official beginning at the first American Lumber Congress held in Chicago, April 14 to 17, 1919. At that time a resolution was passed favoring unification of sizes of all softwood lumber and molding manufactured in the United States. The resolution also issued instructions for the prosecution of the work.

In compliance with this resolution, representatives of the lumber-producing, distributing, and consuming industries met in Chicago on June 30, 1919. At this conference further thought was given to the subject of standard sizes, grades and forms, and nomenclature for softwood lumber, moldings, and shingles, and a plan for future work was outlined. A second conference on standardization was held in Chicago on September 28 and 29, 1920, and some very definite steps toward lumber standardization were taken. At various other conferences and meetings of the American Lumber Congress the National Lumber Manufacturers' Association, and others since that date, the subject of standardization of softwood lumber has been given much attention.

Early in 1922 the Department of Commerce, in connection with its activities on standardization and simplification in industry, became interested in the lumber-standardization movement. This resulted in a conference under the auspices of the Department of Commerce with the National Lumber Manufacturers' Association coöperating, which began May 22, 1922, and which was called for the purpose of furthering the simplification of lumber grades and nomenclature. Conferences with lumber wholesalers, retailers and consumers were held separately and jointly with the lumber manufacturers.

Pursuant to resolutions passed at these conferences a general standardization conference of representatives of all interested industries was held in Chicago on July 21 and 22, 1922. The most

[1] This statement was taken from Standard Grading Specifications for Yard Lumber, by E. P. Ivory, D. G. White, and A. T. Upson, published October, 1923 by the U. S. Department of Agriculture as Circular No. 296.

important step taken at this meeting was the creation of a committee to continue the work of lumber standardization, which is known as the Central Committee on Lumber Standards. Upon this committee were placed representatives of the lumber manufacturers', wholesalers', and retailers' associations, the railroads, the American Institute of Architects, and the Association of Wood Using Industries.

This Central Committee created the Consulting Committee whose duties were to handle the technical phases of lumber standardization and to report periodically its findings to the Central Committee for consideration, approval, and presentation to the entire lumber producing, distributing, and consuming industries.

Several important meetings of the Central Committee on Lumber Standards and conferences of its technical advisory staff, the Consulting Committee on Lumber Standards, have been held wherein the subject of standardization of sizes, grades, and nomenclature of soft wood lumber have been gone into very deeply and much progress made toward the final objectives of the work. Both these committees are still functioning and bringing credit to the industry.

The Forest Service of the Department of Agriculture has for many years been interested in the standardization of lumber products and has spent considerable time upon investigations, results of which would assist in the solution of this problem. With the renewed interest manifested by the lumber producing and consuming industries in the subject of standardization of their raw material, the Forest Service through the Forest Products Laboratory, increased materially the time and study given this phase of its research activities.

The Forest Service also continued its work to develop for softwoods, standard sizes of yard lumber, standard names for the different woods, and individual grade specifications for products, such as, flooring, ceiling and partition. Throughout this work it has sought and received the advice of the Central Committee on Lumber Standards and its Consulting Committee, and in turn has coöperated with those committees in their work.

Early in its study of the grades of lumber the Forest Products Laboratory found there existed, as has been stated, a great similarity between various commercial rules in use. This indicated that underlying present rules was an expression of the collective judgment of manufacturers, distributors, and consumers of lumber. Once this fact was recognized, the problem of producing standard grading rules became not one of formulating specifications altogether new, but rather a work of harmonizing existing grading rules into a grading specification which should be absolutely definite and impossible of misinterpretation, yet sufficiently elastic to permit the use of judgment on the part of the grader in applying the rules.

Library Notes and Book Reviews

The Life of Sir William White

THE LIFE OF SIR WILLIAM WHITE, K.C.B., F.R.S., LL.D., D.Sc. By Frederic Manning, E. P. Dutton & Co., New York, 1923. Cloth, 6 x 9 in., 502 pp., illus., $8.

REVIEWED BY WALTER M. MCFARLAND,[1] NEW YORK, N. Y.

ONE of the celebrities of antiquity in reviewing, near the close of his life, the events which had occurred in his time, remarked, "All of this I saw; much of it I was." This same remark might very well have been made by Sir William White with respect to the history of the British Navy during the half-century from about 1860 to his death in 1913.

Beginning as a shipwright apprentice in the Devonport dockyard in 1859, he was later selected as one of the early students of the Royal School of Naval Architecture and Marine Engineering at South Kensington, where so many of the leaders in the British marine field during the past thirty years were educated. Here he was easily first in a class with other men who later on became almost as famous. On graduation in 1867 he was assigned to the Admiralty, and shortly after became professional secretary to Sir Edward Reed, who was the chief naval architect. It was during this assignment in 1870 that the British turret ship *Captain* capsized, with the result that there was a sensation in shipbuilding circles and an investigation by the Admiralty. In connection therewith White and the late William John did some specially good and original work in calculations respecting stability.

After service for a number of years at the Admiralty, during part of the time as chief assistant to Sir Nathaniel Barnaby, White was in 1883 made the director of construction and general manager of the firm of Sir William Armstrong and Company. Here he had a fine field for his talents and added to his already great reputation. When the time approached for Sir Nathaniel Barnaby's retirement, the Admiralty authorities felt that no one but White could fill the position of Director of Naval Construction. Accordingly he gave up a large salary and bonus with Armstrong to accept the more conspicuous position at a considerably lower salary with the Admiralty. This was in 1885, and from that time until 1902 he was the Director of Naval Construction and responsible for all the vessels of the British navy built during that period, amounting to more than two hundred and fifty, comprising battleships, armored and protected cruisers, destroyers, transports, etc.

It is probably not going too far to say that during this period Sir William White was the foremost figure in naval construction in the world. Possessed of talents of the highest order and of indefatigable industry, he was thoroughly qualified for the position and filled it with conspicuous success. This does not mean, of course, that there were no criticisms. The design of a warship has been said to be always a compromise; consequently there is always room for debate as to whether the compromise has been the wisest one. Nevertheless the consensus of opinion among experts throughout the world was that the work of Sir William White represented the very highest of which the profession was capable. After his retirement from the Admiralty in 1902 he continued active work as a consulting naval architect and had an important part in the design of the Cunard steamers *Mauretania* and *Lusitania*, as well as other important work. He made frequent visits to this country and, at the time of his last one, in 1911, he was the recipient of the John Fritz Medal, which was awarded for notable achievements in naval architecture.

Sir William was a man of very engaging personality and practically every one who had an opportunity of meeting him became a friend. The writer well remembers his first meeting with Sir William, more than twenty-five years ago, and the friendly greeting and interest shown by the famous head of the profession to one of the younger members. Subsequent meetings only served to increase the feeling of personal regard which began at that time.

The work of Mr. Manning is of the type which our Society has planned in its series of biographies of famous members, in that it specializes with respect to the professional side of his career, with incidental mention of his social activities. It is really a history of warship building in Great Britain with frequent comments on that in other countries from about 1855 to 1910. Sir William White was associated with practically every important event from about 1870 on, so that to tell the story of his life was necessarily to tell this history of warship construction.

To any one who takes an interest in navies the book will prove intensely interesting, particularly as important features of design which were a matter of dispute are treated at length. It will also prove interesting to any engineer who takes pride in the work of the leaders of the profession and who desires to keep posted on the history of such an important branch of the profession as naval construction.

It is very interesting in reading this account of warship construction in Great Britain to see that human nature is alike in all countries.

[1] Mgr. Marine Dept., Babcock & Wilcox Co., Mem. A.S.M.E.

We find the same effort on the part of the professional men to produce the very best results, and that this is almost constantly hampered by the parliamentarians with their constant demand for reduced expenditure. Any one who is familiar with the experience in our own country could almost fancy that, with the transposition of names and places, he was reading about something that had occurred in Washington.

As the author had Sir William's own papers, access to government records, and the benefit of consultation with many of his contemporaries, it is safe to say that as a rule the statements in the book are accurate.

The work can be heartily commended to all who are interested in shipbuilding in general and warship construction in particular.

AMERIKANISCHE UND DEUTSCHE GROSSDAMPFKESSEL. By Friedrich Münzinger. Julius Springer, Berlin, 1923, Paper, 6 × 9 in., 178 pp., illus., diagrams, $1.50.

The lack of interchange of ideas between Germany and America during the war and the difference in conditions in the two countries has brought about a greater difference in boilermaking than existed before the war. Dr. Münzinger has thought, because of this, that an accurate picture of American practice in large boiler plants would be of interest to German engineers. He has therefore written this work, which gives a comprehensive survey of American practice and compares those features which he considers important and essential with the corresponding German designs and concepts. Stokers, the use of powdered coal, boilers, superheaters, economizers, air preheaters, high-pressure boilers, boiler settings, feedwater treatment, and heat accumulators are discussed.

DIE DREHEREI UND IHRE WERKZEUGE. Vol. 1; Wirtschaftliche Ausnutzung der Drehbank. By Willy Hippler. Third edition. Julius Springer, Berlin, 1923. Boards, 6 × 9 in., 259 pp., illus., diagrams, tables, $3.25.

The third edition of this work is to appear in two volumes, of which the first is now published. It is concerned with the efficient use of the lathe and the conditions for economical operation. The first section on tool steels discusses methods for determining correct temperatures for hardening and tempering tools, and for recognizing the various sorts of steel. This is followed by a discussion of the economic principles of cutting. Attention is directed to the relation between cutting speed, width of cut, and power consumption, and to the effects of cutting pressure, heat, cutting speed, efficiency and power consumption on the efficiency of the tool. The economic utilization of the lathe is then considered. The final section discusses lathe design in relation to efficiency. The results of much research are summarized in the book, which should interest users and makers.

EINE DARSTELLUNG DES NERNST'SCHEN WARMETHEOREMS. By Victor Fischer. Universitätsdruckerei, Werner & Winter, Frankfort, 1923. Paper, 6 × 9 in., 2 parts.

Starting from geometric conceptions, the author aims to give a rigid presentation of the Nernst heat theorem and to show how it may be generalized and used for obtaining an equation of state which will simultaneously answer for infinitely small temperatures and infinitely great pressures.

ELEMENTS OF RAILROAD ENGINEERING. By William G. Raymond. Fourth edition. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 453 pp., illus., diagrams, maps, tables, $4.

Views the railroad as an organization for the manufacture and sale of transportation, in which the arrangement of the plant is as much an item of design as are the individual machines and processes. The subject of the book is the fixed portion of a railroad plant and the principles that underly its design. The author treats of permanent way, the locomotive and its work, railroad location, construction and betterment surveys. Subjects which are fully covered in special volumes have been treated briefly and generally, while those treated only in books similar to the present one are treated in detail. In the present edition various revisions have been made and the chapter on rails has been practically rewritten.

FINANCIAL ENGINEERING. By O. B. Goldman. Second edition. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 325 pp., diagrams, tables, $3.50.

The aim of the author is to furnish rules by which the engineer may determine the economic value of the different types of machines and installations of machinery. He endeavors to set forth the method of determining the installation which will give the greatest financial efficiency, although not necessarily the greatest mechanical efficiency. The new edition has been revised and extended.

HENLEY'S 222 RADIO CIRCUIT DESIGNS. Norman W. Henley Publishing Co., New York, 1923. Paper, 5 × 8 in., 271 pp., illus., diagrams, tables, $1.

These designs have been selected from the great variety in use with the idea of supplying a selection of typical circuits which will work well, and of explaining these fully, so that the novice can build them with assurance of success. Diagrams are provided for each circuit.

INDUSTRIAL MANAGEMENT. By Richard H. Lansburgh. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 488 pp., illus., charts, tables, $4.50.

Professor Lansburgh has aimed to present a coördinated, simple treatment of the problems, the ideals, and the methods of successful industrial management in a way that is at the same time broad and specific and which indicates the responsibilities of the factory executives to the workers, the owners, and the community. The book covers the whole field and is illustrated by examples chosen from a large variety of industries. The point of view is that of the medium-sized plant.

INDUSTRIEBETRIEBSLEHRE. By E. Heidebroek. Julius Springer, Berlin, 1923. Boards, 8 × 11 in., 285 pp., illus., charts, $4.20.

A thoughtful discussion of the main problems of industrial management, costing, factory organization, wages, depreciation and maintenance, with examples of cost systems for power plants and machine works. The book is not intended for beginners but for manufacturers and managers of experience who wish a connected elucidation of the broad principles of efficient management.

LOGGING. By Ralph Clement Bryant. Second edition. John Wiley & Sons, New York, 1923, Cloth, 6 × 9 in., 556 pp., illus., diagrams, $4.50.

Prepared primarily as a textbook for forest schools, this book is broad in scope and covers only the more important features of operation without attempting to describe local variations. It covers the methods and equipment for the movement of timber from the stump to the manufacturing plant, both by land and by water. Special attention is given to logging railroads. The new edition has been revised and rearranged, and a chapter added on the use of crawler tractors. The bibliography has been enlarged. The book should be useful to those in the industry, as well as to students.

MANUFACTURE OF ELECTRIC STEEL. By Frank T. Sisco. McGraw-Hill Book Co., New York, 1924. Cloth, 6 × 9 in., 304 pp., illus., diagrams, tables, $3.00.

A connected account of the manufacture of steel in the electric furnace, intended for students and also for those engaged in practice. The book describes both apparatus and methods, including the various types of furnaces, the materials, and the various processes in use, both acid and basic.

MANUFACTUPE OF PULP AND PAPER. Vol. 4. By E. C. Tucker and others. McGraw-Hill Book Co., New York, 1924. Cloth, 6 × 9 in., 223 pp., illus., diagrams, $5.

The present volume describes the preparation of rag and other fibers, the treatment of waste papers, beating and refining, loading and sizing, coloring, and paper-making machinery. As in the preceding volumes, the text is the work of a number of specialists, is written in clear, simple language and is very fully illustrated by diagrams.

MEASUREMENT, COMPRESSION AND TRANSMISSION OF NATURAL GAS. By Lester Clyde Lichty. John Wiley & Sons, New York, 1924. Cloth, 6 × 9 in., 523 pp., illus., diagrams, tables, $7.50.

Intended to meet the need for a textbook for students in engineering schools and also to assist the practical man who wishes a knowledge of the principles involved in field work and of the construction and operation of the apparatus used. Technical formulas are developed, so that the factors involved can be studied. Charts are

given which eliminate calculations, and apparatus and machinery are described.

MECHANICAL STOKING. By David Brownlie. Isaac Pitman & Sons, New York and London, 1923. (Pitman's Technical Primers.) Cloth, 4 × 7 in., 234 pp., illus., diagrams, tables, $1.20.

Written from a severely practical point of view. After a short historical account of the beginnings of mechanical stoking, the author describes every make of stoker for stationary steam boilers which is actually on the market in Great Britain today.

METALLURGY OF STEEL. Vol. 1; Metallurgy. By F. W. Harbord and J. W. Hall. Seventh edition. Charles Griffin & Co., London; J. B. Lippincott Co., Philadelphia, 1923. Cloth, 6 × 9 in., 545 pp., illus., plates, diagrams, 32s.

After being out of print for three years, this important work appears in a new edition which exhibits considerable changes. The text has been thoroughly revised throughout and much new matter has been introduced which deals with recent developments in practice. New illustrations have been substituted in many cases. Particular attention is called to the new matter on reversing valves, on the production of steel in the electric furnace, on special and high-speed steels, and on heat treatment.

PRINCIPLES AND PRACTICE OF TELEPHONY; vol. 4, Circuit Refinements and Mechanical Switching. Vol. 5, Mechanical Manual Switching. By Jay G. Mitchell. McGraw-Hill Book Co., New York, 1924. Cloth, 5 × 8 in., 2 vols., illus., $2.50 each.

Volume 4 discusses inter-office trunking, extra-efficient manual equipment, call distribution, two-digit mechanical switching, trunk mechanical switching and mechanical switching traffic.

Volume 5 deals with combinations, including switches; with the apparatus of semi-mechanical systems; and with the mechanical features of equipment for very heavy traffic. As in the other volumes, emphasis is placed on the principles and the apparatus actually used. The books are intended for those engaged in telephone work, who wish a knowledge of its technical principles.

PULVERISED AND COLLOIDAL FUEL. By J. T. Dunn. Ernest Benn, London, 1924. Cloth, 7 × 10 in., 197 pp., illus., 25s.

A review of accomplishment in the use of powdered coal, intended primarily to call its possibilities to the attention of British manufacturers. The author describes the preparation of powdered coal, methods of transporting and firing, ash disposal, costs, advantages and disadvantages. Typical applications for various purposes are described. A brief account of the manufacture and properties of colloidal fuel is included.

DER RADIO AMATEUR. By P. Lertes. Theodor Steinkopff, Dresden and Leipzig, 1924. Paper, 6 × 9 in., 216 pp., illus., diagrams, tables, $1.35.

A comprehensive manual for amateurs. Section one gives in outline the physical and electrical foundations of radio communication. Sections two and three explain in detail the sending and receiving apparatus and their operation. The fourth section gives practical advice to amateur operators, and the concluding section is a brief history of the subject. An appendix of tables and other data includes a brief bibliography.

REFRACTORIES FOR ELECTRIC FURNACES. Second edition. American Electrochemical Society, New York, 1924. Paper, 6 × 9 in., 96 pp., $1.

A collection of papers by various experts, describing the necessary qualities of refractories for electric furnaces and the properties of the refractories available for this use. Most of these papers were presented before the Electric Furnace Association.

STUDIES IN THE ECONOMICS OF OVERHEAD COSTS. By J. Maurice Clark. Univ. of Chicago Press, Chicago, 1923. Cloth, 6 × 9 in., 502 pp., $4.

The subject of this book, Professor Clark says, may be defined as "a study of discrepancies between an ever-fluctuating demand and a relatively inelastic fund of productive capacity, resulting in wastes of partial idleness, and many other economic disturbances. Unused capacity is its central theme." In studying this question of costs which are not traced to units of output or do not vary with output, the author attempts to utilize both the conception of cost of the cost accountant and of the economist, and to draw conclusions which will be of value to the man of business. The book is based on a course given to students of business and political economy at the University of Chicago.

TECHNICAL WRITING. By T. A. Rickard. Second edition. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 5 × 8 in., 337 pp., $2.

Mr. Rickard's book will be useful to every engineer who desires to write clearly, correctly, and pleasantly. He calls attention to many common faults in technical writing, illustrates them by many examples, and shows how they might have been avoided. The advice given is practical and is based on lengthy editorial experience. The new edition has been corrected, partly rewritten, and enlarged by two new chapters.

USEFUL INFORMATION AND TABLES COVERING OXY-ACETYLENE PIPE WELDING AND PIPE DATA. Second edition. Linde Air Products Co., New York, 1923. Paper, 5 × 7 in., 53 pp., illus., tables.

A compilation of practical data on the cost of welding and cutting standard and heavy pipe with the oxy-acetylene torch, on the cost of laying pipe, and the total cost of pipe lines. Dimension tables for patterns for cutting pipe are given.

UTILIZATION OF LOW GRADE AND WASTE FUELS. By W. Francis Goodrich. Ernest Benn, London, 1924. Cloth, 7 × 10 in., 368 pp., illus., diagrams, tables, 42s.

Considers the possibilities of lignite, brown coal, peat, coke breeze, town refuse, wood waste and other waste material. Describes the methods of preparation, the necessary boiler and furnace equipment, machinery for briquetting. Gives some information on the results obtained in practice.

VECTOR ANALYSIS. By C. Runge. E. P. Dutton & Co., New York, n. d. Cloth, 5 × 8 in., 226 pp., $3.50.

A complete, logical treatment of the vectorial analysis of three dimensions, presented in convenient form, suitable for serious students of mathematics. The book is based largely on the work of Grassmann, but uses a simplified notation. A second volume, on the analysis of four and more dimensions, is promised.

WORKING OF STEEL. By Fred H. Colvin, and K. A. Juthe. Second edition. McGraw-Hill Book Co., New York and London, 1922. Cloth, 6 × 9 in., 245 pp., illus., tables, $3.

The authors have collected information, from the best available sources, on the most approved methods for working the steels now in use, and have added the results of their own experience; the result being a useful manual for those engaged in heat treating steel. This edition has been revised and partly rewritten.

Discussion on Stress Distribution

(*Continued from page 132*)

determined by the elastic resilience of the different sets of teeth of the system combined with the moments of inertia of the rotating parts. For a two-wheel system, for example, there existed a separate fundamental and a series of harmonics for each gear wheel. For more than two wheels, resonance might arise from combinations of wheels, besides the periods of the separate wheels. This was a difficulty present in all gear-wheel systems regardless of the material used. Celluloid gearing also must be subject to the same phenomena. This was indeed fortunate, because in a system of celluloid gearing the stresses might be directly measured, and thus the rise and fall of stress with the different natural periods of the system could be followed in a way possible with no other method of study. Valuable results should be obtained from the study of a two-component system by the photoelastic method, and the authors hoped to do some further work on this problem.

Mr. Eksergian's statement that the comparison for steel was correct for static loads only and not for dynamic conditions was of course true as long as the systems of steel and celluloid gearing were not dynamically similar. Elastic similarity only was required for comparisons of systems under a static load. Both elastic and dynamic similarity were requisite for direct comparisons of systems of steel and celluloid gearing under dynamic conditions. This did not mean, however, that valuable results could not be obtained from further studies of rotating pinions by the photoelastic method.